Eastern Research Group, Inc.

# 2020 SUMMER FUEL FIELD STUDY

## *Final*

***Prepared for:***

Texas Commission on Environmental Quality
Air Quality Division
Austin, TX 78711-3087

**September 9, 2020**

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***Prepared by:***

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# ABBREVIATIONS

| | |
|---|---|
| AST | aboveground storage tank |
| ASTM | American Society for Testing and Materials |
| CAS | Chemical Abstracts Service |
| DHA | detailed hydrocarbon analysis |
| E200 | lower volatility percentage |
| E300 | upper volatility percentage |
| EIA | Energy Information Administration |
| ERG | Eastern Research Group, Inc. |
| ETBE | ethyl tert-butyl ether |
| EtOH | ethanol |
| FIPS | Federal Information Processing Standards |
| IATA | International Air Transport Association |
| IC | independent contractor |
| MOVES | Motor Vehicle Emission Simulator |
| MTBE | methyl tert-butyl ether |
| ppm | parts per million |
| PST | petroleum storage tank |
| QA/QC | quality assurance/quality control |
| RVP | Reid vapor pressure |
| SIP | State Implementation Plan |
| SwRI | Southwest Research Institute |
| TAME | tert-amyl methyl ether |
| TCEQ | Texas Commission on Environmental Quality |
| TexN | Texas NONROAD model |
| TxDOT | Texas Department of Transportation |
| U.S. DOT | U.S. Department of Transportation |
| U.S. EPA | U.S. Environmental Protection Agency |
| ULSD | ultra-low-sulfur diesel |
| UST | underground storage tank |
| VOC | volatile organic compound |

# ES.0 EXECUTIVE SUMMARY

Eastern Research Group, Inc. (ERG), along with subcontractor Southwest Research Institute (SwRI), collected fuel samples across Texas in the summer of 2020. All gasoline grades (low, mid, and high) and diesel fuel were sampled at 91 gasoline service stations, covering all of the 25 Texas Department of Transportation (TxDOT) districts. The objective of this study was to develop updated Texas-specific fuel parameter files for use in the U.S. Environmental Protection Agency's (EPA's) Motor Vehicle Emission Simulator (MOVES) [MOVES2014b] model and the Texas Commission on Environmental Quality's (TCEQ) TexN (Texas Nonroad) utility (TexN2).

The SwRI laboratory tested fuel samples for various properties, work that involved speciation of hydrocarbon compounds including oxygenates, determination of Reid vapor pressure (RVP), estimation of sulfur content in fuel, and quantification of aromatics, olefins, distillation analysis, and cetane. Additionally, ERG calculated the lower volatility percentage (E200) and the upper volatility percentage (E300) using the results from the distillation tests.

ERG assigned fuel regions—based on sampling locations and corresponding to the MOVES2014b model's fuel regulatory and fuel distribution boundaries—to all the analytical data records for both gasoline and diesel fuel samples. The fuel parameters for gasoline and diesel were averaged for each of these fuel regions. For gasoline, ERG calculated weighted averages across the fuel grades using the latest available fuel sales data for Texas. These data were then used to develop updated fuel parameter files for MOVES2014b and TexN2.

Additionally, the ERG team performed a second round of sampling and lab analysis for the sampling stations in the Houston district. This round was performed to determine temporal variability of fuel properties within the same district and at the individual station level. ERG also compiled TxDOT district-level fuel parameter data from previous studies and performed a trends analysis for 2003–2020 fuel parameter data at the district level.

## 1.0 INTRODUCTION

To maintain confidence in the fuel parameters it uses in developing on-road and nonroad emission inventories, trend analyses, and control strategy analyses, the TCEQ has undertaken a program to periodically collect and analyze fuel samples. The results ensure the accuracy of location-specific fuel information and provide the best data available for analyses to support Texas State Implementation Plan (SIP) and control strategy development.

For this project, the TCEQ contracted ERG to develop updated, Texas-specific fuel parameter rules for use with the MOVES2014b and TexN2 emission models. To that end, ERG was also tasked with developing physical properties and speciation profiles and with sampling and testing gasoline and diesel fuel at retail stations across Texas.

ERG's subcontractor, SwRI, took samples of regular unleaded gasoline, mid-grade gasoline, premium-grade gasoline, and ultra-low-sulfur diesel (ULSD) fuel from 91 retail gas stations, representing the 25 different TxDOT districts. SwRI then tested these samples for various properties. The tests involved speciation of volatile organic compounds (VOCs) including oxygenates; determination of RVP and sulfur content in gasoline; and quantification of aromatics, cetane, and sulfur in diesel fuel. Distillation analysis tests were also performed on the collected gasoline and diesel samples.

The following sections of this report summarize the sample collection plan, sample collection and lab analysis steps, data analyses on the collected gasoline and diesel test data and their results, the development of Texas-specific updated fuel parameter files for use in EPA's MOVES2014b model and TCEQ's TexN2 utility, temporal analysis comparing round 1 and round 2 results for the Houston TxDOT district, and analysis of trends between the 2020 summer data and available data from previous years (2003–2017).

## 2.0 SAMPLING PLAN

ERG developed a fuel sampling plan that SwRI carried out during the summer of 2020 (June/July 2020). ERG began with the list of retail stations sampled in the 2017 Summer Fuel Field Study (ERG, 2017), which served as the primary sampling candidates for fuel sampling during the summer of 2020. ERG also developed a list of alternate sampling candidates in case sampling at the primary candidate locations was not possible.

### 2.1 Fuel Sampling Plan and Site Selection

ERG developed a sampling plan that specified the number of stations per TxDOT district, the total number of samples (including number of diesel and gas samples, across gas grades), and the allocation of stations across the districts. The sampling plan specifications included the following:

- Each fuel sampling district had at least three sample stations;
- Both diesel and gasoline samples were collected at each location;
- Regular, mid-grade, and premium gasoline grades were sampled; and
- Gasoline and diesel samples were collected separately (no compositing).

This approach required a lab test of every sample. As a result, this approach limited the total number of stations that could be sampled. However, it provided an indication of differences *within* areas that a compositing approach would not have revealed. Specifically, it enabled the determination of minimum, maximum, and average fuel parameter values, instead of just averages for each region. This characterization is more consistent with MOVES modeling in that it will allow the TCEQ to specify maximum and average parameter values for model inputs, such as fuel sulfur levels.

Table 1 summarizes the number of stations that were sampled for each district. At each station, ERG obtained three gasoline samples and one diesel sample.

**Table 1. Initial Sampling Plan Summary Table**

| TxDOT District | Number of Stations | Area Ozone Standard Designation |
|---|---|---|
| Abilene | 3 | Attainment |
| Amarillo | 3 | Attainment |
| Atlanta | 3 | Attainment |
| Austin | 5 | Attainment |
| Beaumont | 5 | Attainment (Beaumont-Port Arthur Maintenance Area) |
| Brownwood | 3 | Attainment |
| Bryan | 3 | Attainment |
| Childress | 3 | Attainment |
| Corpus Christi | 3 | Attainment |
| Dallas | 4 | Nonattainment (Dallas-Fort Worth Area) |
| El Paso | 5 | Attainment |
| Fort Worth | 4 | Nonattainment (Dallas-Fort Worth Area) |
| Houston | 7* | Nonattainment (Houston-Galveston-Brazoria Area) |
| Laredo | 3 | Attainment |
| Lubbock | 3 | Attainment |
| Lufkin | 3 | Attainment |
| Odessa | 3 | Attainment |
| Paris | 3 | Attainment |
| Pharr | 3 | Attainment |
| San Angelo | 3 | Attainment |
| San Antonio | 5 | Nonattainment (Bexar County Area) |
| Tyler | 5 | Attainment area |
| Waco | 3 | Attainment |
| Wichita Falls | 3 | Attainment |
| Yoakum | 3 | Attainment |
| **Total** | **91** | |

* These stations were sampled a second time later in the summer.

The retail stations that were sampled were all "active" retail establishments. The master sampling list did not include non-retail establishments such as bulk fuel terminals, fleet refueling stations, and automobile dealers. All 91 retail stations in the master list were identified as selling both gasoline and diesel fuel and had tank capacities greater than or equal to 10,000 gallons.

As noted above, ERG also developed a list of alternate sampling stations (to be used if a primary station was out of business, was temporarily closed, did not sell three grades of gasoline, or was otherwise inaccessible). To develop this list, ERG began with the TCEQ's latest petroleum storage tank (PST) data, obtained via email (Regan, 2020). The PST datasets contained the following information on facilities with underground storage tanks (USTs) and/or aboveground storage tanks (ASTs):

- Facility information—status (active or inactive), type (retail, aircraft, fleet, etc.), location, number of tanks, and enforcement action;
- Tank information—tank size and status (in-use, removed, etc.); and
- Composition information—tank-specific information including fuel type.

The datasets only included active retail establishments and did not include USTs that had a storage capacity under 10,000 gallons.

Data from the UST and AST datasets were merged into one master file. From this merged list, ERG filtered out the establishments that had active enforcement actions against them from the TCEQ. The next step was to include only stations that sold both gasoline and diesel. Each of the retail stations on the list was then assigned to the appropriate TxDOT district based on county.

ERG then chose six to 14 alternate sampling stations for each TxDOT region, the goal being to select twice as many alternate stations as primary ones. ERG chose retail stations with the most tanks as alternate locations; as well, most alternate stations were within the same cities as the primary stations.

In an additional step, ERG checked the PST data to verify if the primary candidates (from the 2017 study) were still active. Out of the 91 primary candidates, 27 were not available by the same name in the PST data. ERG was able to match 21 of these 27 stations based on physical address. These 21 stations were present in the latest TCEQ data under different names (potentially due to change of ownership). ERG could not match the remaining six stations by name or by physical address (potentially due to temporary or permanent shutdown). For each of these six cases, ERG chose a replacement sampling location in the same city.

Additionally, one facility in the 2017 master list has an enforcement action listed against it in the latest PST data. ERG dropped this facility from the 2020 master sampling list and added a replacement.

## 2.2 Sampling: Round 1

During the initial sampling in June 2020, sampling was not possible at two retail gas stations out of the 91 master sampling sites:

- One sampling site did not carry all three grades of gasoline; and
- One sampling site was a private fleet refueling station.

For these two sites, sampling was conducted at the closest alternate sampling site.

During round 1 of sampling, SwRI took 273 gasoline samples (91 stations, three gasoline grades sampled at each station) and 91 diesel fuel samples (one diesel fuel sample per station) across the 25 TxDOT districts. The list of final sampling locations is presented in Attachment 1.

## 2.3 Sampling: Round 2

ERG oversaw a second round of testing to better understand the temporal variability of fuel composition within a district. To enable a preliminary, station-level assessment of this variability, SwRI took a second round of samples from a small subset of the fueling stations (the seven sites in the Houston district), ensuring that enough time elapsed for complete tank turnover (four weeks).

## 3.0 SAMPLING AND LABORATORY ANALYSIS

This section describes the sampling protocol and laboratory tests performed for this study. SwRI provided sample containers and packaging, gasoline and diesel sample acquisition services from retail stations, sample shipping, sample handling, and sample testing for summer fuels in 2020.

### 3.1 Retail Station and Sample Collection and Handling Procedures

Independent contractors (ICs) working with SwRI acquired the fuel samples from retail stations. Each IC received written instructions, master and alternate sampling lists, sampling procedures, sample containers, shipping instructions, etc., from SwRI. All contractors were instructed on retail station sampling procedures, with special emphasis on sample handling and safe disposal of flushed fuel.

SwRI used fuel sample containers and shipping cartons approved by the U.S. Department of Transportation (DOT) and the International Air Transport Association (IATA). Trained staff assembled the boxes at SwRI, and all appropriate shipping materials were provided to the ICs along with FedEx-approved instructions for shipment of hazardous materials/dangerous goods. The containers were delivered cleaned and dried to the ICs.

To take each sample, the IC purged 3 gallons of gasoline product through the pump nozzle before taking each sample—or ½ gallon, if a customer had just bought the appropriate grade of fuel. The IC recorded the temperature of the flushed sample. Immediately after flushing the fuel from the pump, the IC attached a spacer (if needed) to the pump nozzle. A nozzle extension was inserted into the sample container; the pump nozzle was in turn inserted into the extension with its slot over the air bleed hole. The sample container was slowly filled through the nozzle extension to 70% to 85% full. The nozzle extension was removed and the sample container was capped and sealed. Checks were also performed for leaks. The sample was then prepared for air shipment. The ICs also recorded the type of fuel pump pad material (e.g., concrete, asphalt) at each sampling station.

For a diesel sample, the IC filled the sample container slowly to 70% to 85% full. The sample container was then capped and sealed. The sealed container was then checked for leaks and prepared for air shipment. The IC also recorded the sulfur content labeling of the diesel pump used to obtain the diesel sample.

The ICs used FedEx to ship samples back to SwRI. Members of the SwRI shipping and receiving team meet regularly with FedEx and attend IATA and International Civil Aviation Association hazardous materials shipping and handling training sessions to keep abreast of current regulations. All samples were chilled.

## 3.2 Laboratory Testing

SwRI carried out all testing in its Petroleum Products Research Department laboratories, part of its Automotive Products and Emissions Research Division. The facilities are at 6220 Culebra Road, San Antonio, Texas.

### 3.2.1 Gasoline Testing

SwRI tested individual regular, mid-grade, and premium gasoline samples. There was no compositing of samples, as discussed above. Key testing methods included:

- RVP (ASTM D5191-19);
- Sulfur (ASTM D2622-16);
- Distillation (ASTM D86-18);
- Benzene (ASTM D3606-19);
- Total aromatics (ASTM D5769-15);
- Olefins (ASTM D6550-15);
- Oxygenates (ASTM D5599-18); and
- Detailed hydrocarbon analysis (ASTM D6729-14).

Attachment 2 provides test results for all 273 gasoline samples collected in round 1. (These do not include the round 2 sampling at the seven locations in the Houston district.)

### 3.2.2 Diesel Testing

Diesel samples were acquired from all 91 sampling locations. Testing performed on each diesel sample included:

- Cetane number (ASTM D613-18a);
- Calculated cetane index (ASTM D976-06 [2016]);
- API gravity (ASTM D287-12b);
- Specific gravity (ASTM D1298-12b [2017]);
- Sulfur (ASTM D5453-19a);
- Nitrogen (ASTM D4629-17);
- Total aromatic content (ASTM D5186-19);
- Polycyclic aromatic content (ASTM D5186-19);
- Distillation (ASTM D86-18); and
- Flash point (ASTM D93-19).

Attachment 3 provides sample identification information and test results for all the diesel samples collected in the initial sampling round. (Again, these do not include round 2 samples.)

Summer fuel studies performed in the past used results from ASTM D1319 testing for aromatics, olefins, and saturates for both diesel and gasoline fuel samples. This ASTM test (D1319) was not conducted during this project because the dye required for this testing does not meet current ASTM quality standards. Therefore, alternate tests were performed for aromatics (D5769) and olefins (D6550). For this reason, saturates (% volume) data for both gasoline and diesel fuel samples collected during the summer of 2020 are not available. However, there is no impact on the development of MOVES2014b and TexN2 fuel parameters files as the saturates fuel parameter is not required. In addition, the diesel fuel trends analysis does not include aromatics, olefins, and saturates for 2020.

## 4.0 DEVELOPING UPDATED FUEL PARAMETERS FOR TEXAS

ERG used gasoline and diesel fuel sample analysis data collected by SwRI to develop fuel parameter input data for EPA's MOVES model (MOVES2014b) and TCEQ's Texas NONROAD emissions estimation utility (TexN2). Fuel parameter data were developed for each county in Texas using the fuel sample analysis data.

### 4.1 Gasoline Analysis

The SwRI gasoline data needed significant formatting before ERG could develop the average fuel parameter values. SwRI transmitted the gasoline data in two separate datasets: the "DHA" dataset for the detailed hydrocarbon analysis results and the "NoDHA" dataset for all other test results for gasoline samples. The DHA data were compiled in a single worksheet with a header, group summary, group component data, and group carbon data for each sample. The header section of the DHA data contained service station and sample information. The group summary section contained composition information (i.e., % volume, % weight, and % mol) for various hydrocarbon groups (e.g., paraffins, aromatics, olefins, oxygenates). The group component section contained composition information for the various sub-components (i.e., ETBE, MTBE, TAME, ethanol, propane, i-butane, etc.) of the groups listed under the group summary section. This section also includes the Chemical Abstracts Service (CAS) number for each of the sub-components. ERG extracted only the required DHA parameters into one flat file.

Historically, data from the DHA were used to report data for specific contaminants from each sample (e.g., benzene, ETBE, MTBE, TAME, EtOH, aromatics, olefins). However, beginning in 2011, data for these parameters were also reported using the ASTM D5599-18 test, while aromatics and olefins were determined using the ASTM D5769-15 and D6550-15 test methods. For this study, ERG used the data results obtained from the "NoDHA" analysis using the ASTM D5599-18, ASTM D5769-15, and ASTM D6550-15 test methods to develop the required fuel parameters for MOVES2014b and TexN2. The "NoDHA" dataset was already in a flat file format and needed no further processing. Test results for the following fuel parameters were obtained from the "NoDHA" dataset for each gasoline sample for further analysis:

- RVP;
- Sulfur;

- Total Aromatics;
- Olefins;
- Benzene;
- Oxygenates—ethanol, ETBE, MTBE, and TAME; and
- Distillation results for 50% and 90% of sample fraction (Evap_50 and Evap_90).

Using the distillation results for 50% and 90% sample fractions, ERG calculated the lower volatility percentage (E200) and upper volatility percentage (E300).

ERG assigned counties and county Federal Information Processing Standards (FIPS) codes to the sampling results based on sampling station location. EPA's MOVES2014b model contains county-to-fuel region mapping. ERG exported these data from the model and assigned the fuel region to each of the samples based on the county of the sampling station. All the counties in Texas are assigned to one of the state's six fuel regions. The fuel region IDs follow the format provided below.

> VVWWXXYYZZ - VV=fuel PADD, WW=max summer RVP x.y, XX=00 1 psi waiver, 01 no waiver, YY=min ethanol vol%, ZZ=reserved

Since three grades of gasoline were sampled, regular, mid-grade, and premium-grade data were extracted separately. Required fuel parameters (e.g., RVP, fuel sulfur, benzene, ethanol, MTBE, ETBE, and TAME) were then averaged by fuel region and by gasoline grade. For example, benzene was averaged for each of the six fuel regions, for regular, mid-grade, and premium-grade gasoline individually.

ERG then calculated a weighted average across all three gasoline grades for each fuel region based on the latest refiner motor gasoline sales data obtained from the Energy Information Administration (EIA). EIA sales data for Texas in 2019 indicate regular gasoline constituted 86.6% of the market, mid-grade gasoline constituted 6.3%, and premium gasoline constituted 7.1% (EIA, 2020).

## 4.2 Diesel Analysis

The SwRI diesel analysis data were in a flat file format, similar to the "NoDHA" file for gasoline data, as described in Section 4.1. The diesel data contained information on the service station where the sample was collected, fuel composition data, and distillation data. The diesel fuel analysis evaluated the following fuel parameters:

- Specific gravity;
- Aromatics;
- Sulfur content;
- Cetane number; and
- Distillation data (Evap_50).

The diesel fuel test data were grouped by fuel region, and average fuel parameters were calculated for each of the six fuel regions.

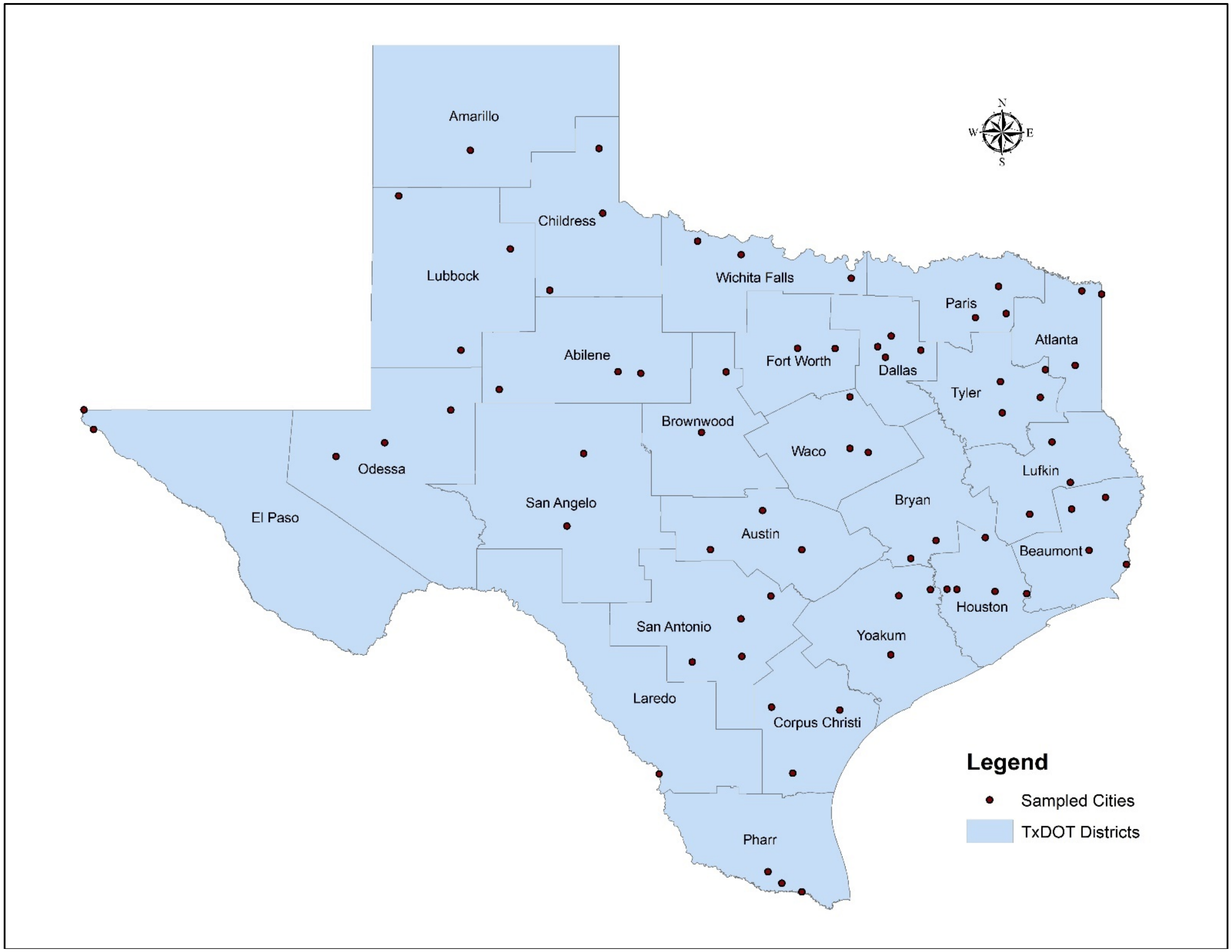
## 4.3 Updated Fuel Parameter Files

Once the fuel parameter averages were calculated at the fuel region level for gasoline samples and for diesel samples, ERG developed county-level fuel parameter averages. ERG used the county-to-fuel region allocation data from MOVES2014b to assign fuel-region-level fuel parameter average values to each county within the same fuel region.

The summer fuel studies conducted for the TCEQ in 2008, 2011, 2014, and 2017 aggregated the sampling results at the TxDOT district level and developed fuel parameter averages for each district. These district-level averages were then assigned to all the counties located within the same district. In order to perform a 2003–2020 trends analysis for selected fuel parameters, ERG developed district-level fuel parameter averages using the 2020 sampling results. These district-level average values were used only for the trends analysis.

Figure 1 indicates the TxDOT district boundaries and sampling city locations.

**Figure 1. TxDOT Districts and Sampling Areas**



The fuel parameter data for the 2020 summer sampling results were compiled, processed, and formatted for use as an input file for the MOVES2014b model. ERG first used the County Data Manager module in the MOVES2014b model and exported the fuel data template as an Excel file. Next, ERG updated the fuel formulation and the fuel supply tables in the fuel template with the 2020 summer fuel sampling data. All other tables related to fuel data were left as defaults.

This process resulted in populating an Excel spreadsheet containing the 2020 summer fuel data collected for TCEQ. This file may be edited according to user needs and imported into the model using the County Data Manager.

Similarly, the fuel data template was exported from the TexN2 utility in spreadsheet format and was updated with the applicable 2020 summer fuel sampling data. The spreadsheets containing data to update the fuel parameter inputs for MOVES2014b and TexN2 are provided in Attachment 4a. The spreadsheet also contains the MySQL scripts that are needed to update and load the new fuel parameter data into TexN2.

## 4.4 Findings

Table 2 shows the average fuel-region-level values for selected fuel parameters for gasoline. Table 3 does the same for diesel fuel.

Selected fuel parameters from the initial round gasoline DHA and NoDHA datasets in flat-file format, fuel-region-level averages by gasoline grade, fuel-region-level weighted averages across all grades, and county-level averages are provided in Attachment 4b. The same attachment provides diesel fuel test results, fuel-region-level averages, and county-level averages for diesel fuel.

## Table 2. Gasoline Fuel Properties by Fuel Region (Summer 2020)

| Fuel Region | RVP | Sulfur (ppm) | Aromatics (% vol) | Olefins (% vol) | Benzene (% vol) | EtOH (% vol) | MTBE (% vol) | ETBE (% vol) | TAME (% vol) | E200 (%) | E300 (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100000000 | 9.20 | 8.31 | 14.72 | 11.55 | 0.66 | 9.54 | 0 | 0 | 0 | 59.79 | 90.43 |
| 1370011000 | 7.30 | 10.60 | 15.81 | 9.10 | 0.47 | 9.60 | 0 | 0 | 0 | 48.49 | 85.08 |
| 178000000 | 7.50 | 8.17 | 27.19 | 5.47 | 0.65 | 9.60 | 0.00025 | 0 | 0 | 46.49 | 84.18 |
| 178010000 | 7.77 | 8.63 | 22.22 | 8.69 | 0.58 | 9.56 | 0.000044 | 0 | 0 | 49.64 | 84.60 |
| 300000000 | 9.34 | 8.04 | 22.60 | 9.77 | 0.68 | 8.96 | 0 | 0 | 0 | 53.34 | 85.68 |
| 370010000 | 6.84 | 4.89 | 24.24 | 5.94 | 0.48 | 9.50 | 0 | 0 | 0 | 44.61 | 84.63 |
| ***Average*** | ***7.99*** | ***8.11*** | ***21.13*** | ***8.42*** | ***0.59*** | ***9.46*** | ***0.000048*** | ***0*** | ***0*** | ***50.39*** | ***85.77*** |
| ***Min*** | ***6.84*** | ***4.89*** | ***14.72*** | ***5.47*** | ***0.47*** | ***8.96*** | **—** | ***0*** | ***0*** | ***44.61*** | ***84.18*** |
| ***Max*** | ***9.34*** | ***10.60*** | ***27.19*** | ***11.55*** | ***0.68*** | ***9.60*** | ***0.00025*** | ***0*** | ***0*** | ***59.79*** | ***90.43*** |
| ***Range*** | ***2.50*** | ***5.71*** | ***12.47*** | ***6.08*** | ***0.20*** | ***0.64*** | ***0.00025*** | ***0*** | ***0*** | ***15.18*** | ***6.25*** |
| ***Standard Deviation*** | ***1.037*** | ***1.84*** | ***4.88*** | ***2.32*** | ***0.089*** | ***0.25*** | ***0.00010*** | ***0*** | ***0*** | ***5.47*** | ***2.34*** |

**Table 3. Diesel Fuel Properties by Region (Summer 2020)**

| Region | Aromatics, % wt | Sulfur, ppm | Cetane No. | Specific Gravity | T50, °F |
|---|---|---|---|---|---|
| 100000000 | 12.85 | 2.10 | 54.93 | 0.83 | 513.30 |
| 1370011000 | 24.78 | 5.16 | 48.15 | 0.84 | 518.98 |
| 178000000 | 24.04 | 3.69 | 45.97 | 0.84 | 497.00 |
| 178010000 | 22.73 | 6.72 | 49.63 | 0.84 | 503.56 |
| 300000000 | 21.83 | 5.65 | 50.21 | 0.84 | 501.38 |
| 370010000 | 22.95 | 6.36 | 50.20 | 0.84 | 512.82 |
| ***Average*** | ***21.53*** | ***4.95*** | ***49.85*** | ***0.84*** | ***507.84*** |
| ***Min*** | ***12.85*** | ***2.10*** | ***45.97*** | ***0.83*** | ***497.00*** |
| ***Max*** | ***24.78*** | ***6.72*** | ***54.93*** | ***0.84*** | ***518.98*** |
| ***Range*** | ***11.93*** | ***4.62*** | ***8.96*** | ***0.017*** | ***21.98*** |
| ***Standard Deviation*** | ***4.38*** | ***1.75*** | ***2.97*** | ***0.0060*** | ***8.44*** |

## 5.0 TEMPORAL VARIABILITY AND TREND ANALYSIS

For 2020, ERG and SwRI conducted a second round of sampling and lab analysis for the seven stations in the Houston district. These round 2 data enabled ERG to analyze the temporal variation of fuel parameters within a single district and at individual retail stations. This section describes that analysis, along with the trends analyses ERG performed using selected fuel parameter data from previous years (2003–2017) and the results from the sampling conducted in summer 2020.

### 5.1 Temporal Variability (Round 1 vs. Round 2 Data)

For the Houston district, SwRI sampled gasoline and diesel fuel from seven retail gasoline stations during the initial sampling in the first week of June 2020, then again four weeks later. (The four-week wait period was to ensure complete tank turnover at all seven locations.) Table 4 lists the seven stations.

**Table 4. Houston District Sampling Stations**

| Station ID | Station Name |
|---|---|
| 1 | Baytown Express Travel Center |
| 2 | Flying J Travel Plaza 729 |
| 3 | Flying J Travel Plaza 740 |
| 4 | Loves Travel Stop 234 |
| 5 | Loves Travel Stop 315 |
| 6 | Loves Travel Stop 401 |
| 7 | Loves Travel Stop 468 |

Test results for round 2 were identical in format to the initial sampling data received from SwRI. ERG carried out the same processing steps for the round 2 test results as for the round 1 results, as described in Section 4 of this report. Tables 5 and 6 compare the round 1 and round 2 results. Table 5 presents the results for gasoline samples; Table 6 presents diesel fuel sampling results.

**Table 5. Station-Specific Gasoline Fuel Results, Round 1 vs. Round 2**

| Station ID | Fuel Component | Round 1 Results | Round 2 Results | Difference (R2 – R1) | % Difference |
|---|---|---|---|---|---|
| 1 | RVP, psi | 7.55 | 7.35 | -0.19 | -2.56% |
| | Benzene, % volume | 0.47 | 0.51 | 0.04 | 7.95% |
| | Aromatics, % volume | 14.02 | 18.41 | 4.39 | 31.30% |
| | Olefins, % volume | 9.96 | 10.45 | 0.49 | 4.93% |
| | ETOH, % volume | 9.51 | 9.39 | -0.12 | -1.22% |
| | MTBE, % volume | 0 | 0 | 0 | 0% |
| | ETBE, % volume | 0 | 0 | 0 | 0% |
| | TAME, % volume | 0 | 0 | 0 | 0% |
| | Sulfur, ppm | 18.84 | 17.20 | -1.64 | -8.70% |
| | E200 | 49.66 | 29.54 | -20.12 | -40.52% |
| | E300 | 85.12 | 62.75 | -22.37 | -26.28% |
| 2 | RVP, psi | 6.95 | 6.76 | -0.19 | -2.74% |
| | Benzene, % volume | 0.47 | 0.41 | -0.06 | -13.07% |
| | Aromatics, % volume | 21.64 | 21.21 | -0.43 | -1.99% |
| | Olefins, % volume | 9.00 | 8.21 | -0.80 | -8.87% |
| | ETOH, % volume | 9.56 | 9.62 | 0.06 | 0.63% |
| | MTBE, % volume | 0 | 0 | 0 | 0% |
| | ETBE, % volume | 0 | 0 | 0 | 0% |
| | TAME, % volume | 0 | 0 | 0 | 0% |
| | Sulfur, ppm | 7.63 | 7.71 | 0.08 | 1.09% |
| | E200 | 47.99 | 26.43 | -21.56 | -44.93% |
| | E300 | 82.38 | 61.25 | -21.13 | -25.65% |
| 3 | RVP, psi | 6.89 | 6.50 | -0.40 | -5.77% |
| | Benzene, % volume | 0.48 | 0.37 | -0.11 | -23.64% |
| | Aromatics, % volume | 21.09 | 20.96 | -0.13 | -0.63% |
| | Olefins, % volume | 8.38 | 9.25 | 0.87 | 10.35% |
| | ETOH, % volume | 9.50 | 9.32 | -0.18 | -1.90% |
| | MTBE, % volume | 0 | 0 | 0 | 0% |
| | ETBE, % volume | 0 | 0 | 0 | 0% |
| | TAME, % volume | 0 | 0 | 0 | 0% |
| | Sulfur, ppm | 7.14 | 7.13 | -0.01 | -0.16% |
| | E200 | 48.11 | 24.85 | -23.26 | -48.35% |
| | E300 | 82.65 | 59.96 | -22.69 | -27.45% |
| 4 | RVP, psi | 7.15 | 7.38 | 0.23 | 3.26% |
| | Benzene, % volume | 0.44 | 0.54 | 0.10 | 22.90% |
| | Aromatics, % volume | 16.02 | 16.74 | 0.73 | 4.55% |
| | Olefins, % volume | 8.54 | 9.56 | 1.03 | 12.01% |
| | ETOH, % volume | 9.47 | 9.30 | -0.17 | -1.75% |
| | MTBE, % volume | 0 | 0 | 0 | 0% |

**Table 5. Station-Specific Gasoline Fuel Results, Round 1 vs. Round 2**

| Station ID | Fuel Component | Round 1 Results | Round 2 Results | Difference (R2 – R1) | % Difference |
|---|---|---|---|---|---|
| | ETBE, % volume | 0 | 0 | 0 | 0% |
| | TAME, % volume | 0 | 0 | 0 | 0% |
| | Sulfur, ppm | 8.31 | 8.69 | 0.38 | 4.55% |
| | E200 | 48.32 | 29.60 | -18.72 | -38.73% |
| | E300 | 84.32 | 64.91 | -19.41 | -23.02% |
| 5 | RVP, psi | 7.96[1] | 7.30 | -0.65 | -8.23% |
| | Benzene, % volume | 0.51 | 0.50 | -0.01 | -2.54% |
| | Aromatics, % volume | 12.60 | 16.86 | 4.25 | 33.76% |
| | Olefins, % volume | 9.05 | 9.27 | 0.22 | 2.43% |
| | ETOH, % volume | 9.78 | 9.85 | 0.07 | 0.73% |
| | MTBE, % volume | 0 | 0 | 0 | 0% |
| | ETBE, % volume | 0 | 0 | 0 | 0% |
| | TAME, % volume | 0 | 0 | 0 | 0% |
| | Sulfur, ppm | 9.76 | 10.63 | 0.86 | 8.86% |
| | E200 | 49.53 | 28.57 | -20.97 | -42.33% |
| | E300 | 86.52 | 63.81 | -22.71 | -26.25% |
| 6 | RVP, psi | 7.73 | 7.63 | -0.10 | -1.28% |
| | Benzene, % volume | 0.52 | 0.54 | 0.02 | 3.84% |
| | Aromatics, % volume | 14.95 | 16.57 | 1.62 | 10.86% |
| | Olefins, % volume | 8.57 | 8.92 | 0.36 | 4.16% |
| | ETOH, % volume | 9.44 | 9.24 | -0.19 | -2.03% |
| | MTBE, % volume | 0 | 0 | 0 | 0% |
| | ETBE, % volume | 0 | 0 | 0 | 0% |
| | TAME, % volume | 0 | 0 | 0 | 0% |
| | Sulfur, ppm | 14.20 | 9.29 | -4.90 | -34.54% |
| | E200 | 48.75 | 32.01 | -16.75 | -34.35% |
| | E300 | 85.80 | 64.38 | -21.42 | -24.97% |
| 7 | RVP, psi | 7.17 | 7.29 | 0.12 | 1.71% |
| | Benzene, % volume | 0.47 | 0.53 | 0.07 | 14.12% |
| | Aromatics, % volume | 14.10 | 17.24 | 3.15 | 22.34% |
| | Olefins, % volume | 9.80 | 9.91 | 0.11 | 1.08% |
| | ETOH, % volume | 9.58 | 9.32 | -0.26 | -2.72% |
| | MTBE, % volume | 0 | 0 | 0 | 0% |
| | ETBE, % volume | 0 | 0 | 0 | 0% |
| | TAME, % volume | 0 | 0 | 0 | 0% |
| | Sulfur, ppm | 12.95 | 8.40 | -4.55 | -35.10% |

[1] Higher RVP values measured for all gasoline grades in Round 1 samples from station 5. COVID-19 pandemic resulted in lower than normal demand for gasoline and potentially incomplete winter gasoline turnover. Refer to page 28 for clarification on higher RVP values for some gasoline samples.

**Table 5. Station-Specific Gasoline Fuel Results, Round 1 vs. Round 2**

| Station ID | Fuel Component | Round 1 Results | Round 2 Results | Difference (R2 – R1) | % Difference |
|---|---|---|---|---|---|
| | E200 | 47.70 | 30.14 | -17.57 | -36.83% |
| | E300 | 84.29 | 64.24 | -20.06 | -23.80% |

As Table 5 indicates, the round 1 and round 2 gasoline samples for the Houston district stations show substantial variations. The largest decrease between the round 1 and round 2 results is for E200 and E300, and the largest increase is for aromatics. The highest increase overall is for station 5, where the aromatics value of gasoline samples increased by about 34%. The largest overall decrease (-48.4%) is for the E200 values for station 3.

**Table 6. Station-Specific Diesel Fuel Results, Round 1 vs. Round 2**

| Station ID | Fuel Component | Round 1 Results | Round 2 Results | Difference (R2 – R1) | % Difference |
|---|---|---|---|---|---|
| 1 | Specific gravity | 0.85 | 0.85 | 0.0002 | 0.02% |
| | Aromatics, % volume | 28.01 | 28.43 | 0.42 | 1.50% |
| | Sulfur, ppm | 7.31 | 6.65 | -0.66 | -9.04% |
| | Cetane number | 46.0 | 47.9 | 1.90 | 4.13% |
| | T50, °F | 520.0 | 520.7 | 0.70 | 0.13% |
| 2 | Specific gravity | 0.86 | 0.85 | -0.003 | -0.29% |
| | Aromatics, % volume | 29.36 | 28.35 | -1.01 | -3.44% |
| | Sulfur, ppm | 4.64 | 4.01 | -0.62 | -13.42% |
| | Cetane number | 47.1 | 48.0 | 0.90 | 1.91% |
| | T50, °F | 552.2 | 550.1 | -2.10 | -0.38% |
| 3 | Specific gravity | 0.86 | 0.85 | -0.01 | -0.99% |
| | Aromatics, % volume | 31.65 | 28.74 | -2.91 | -9.19% |
| | Sulfur, ppm | 4.90 | 4.88 | -0.02 | -0.41% |
| | Cetane number | 46.6 | 48.5 | 1.90 | 4.08% |
| | T50, °F | 558.5 | 542.1 | -16.40 | -2.94% |
| 4 | Specific gravity | 0.84 | 0.85 | 0.004 | 0.45% |
| | Aromatics, % volume | 21.96 | 26.56 | 4.60 | 20.95% |
| | Sulfur, ppm | 4.41 | 4.68 | 0.27 | 6.03% |
| | Cetane number | 48.7 | 47.1 | -1.60 | -3.29% |
| | T50, °F | 525.9 | 525.0 | -0.90 | -0.17% |
| 5 | Specific gravity | 0.85 | 0.85 | -0.0002 | -0.02% |
| | Aromatics, % volume | 23.64 | 26.33 | 2.69 | 11.38% |
| | Sulfur, ppm | 5.03 | 4.76 | -0.28 | -5.46% |
| | Cetane number | 47.0 | 48.3 | 1.30 | 2.77% |
| | T50, °F | 522.6 | 517.3 | -5.30 | -1.01% |
| 6 | Specific gravity | 0.85 | 0.85 | -0.002 | -0.22% |
| | Aromatics, % volume | 25.46 | 26.06 | 0.60 | 2.36% |
| | Sulfur, ppm | 4.65 | 5.06 | 0.42 | 9.02% |
| | Cetane number | 47.3 | 49.1 | 1.80 | 3.81% |
| | T50, °F | 527.4 | 531.1 | 3.70 | 0.70% |

**Table 6. Station-Specific Diesel Fuel Results, Round 1 vs. Round 2**

| Station ID | Fuel Component | Round 1 Results | Round 2 Results | Difference (R2 – R1) | % Difference |
|---|---|---|---|---|---|
| 7 | Specific gravity | 0.84 | 0.85 | 0.003 | 0.37% |
| | Aromatics, % volume | 24.60 | 26.26 | 1.66 | 6.75% |
| | Sulfur, ppm | 4.92 | 4.81 | -0.11 | -2.18% |
| | Cetane number | 47.5 | 48.6 | 1.10 | 2.32% |
| | T50, °F | 526.9 | 530.5 | 3.60 | 0.68% |

Round 1 and round 2 diesel fuel sampling results indicate significant variation for diesel fuel aromatics values and sulfur levels. The aromatics values range from a decrease of 9% to an increase of about 21%. They exhibit a general upward trend for all stations—except stations 2 and 3, which show modest decreases of about 3% and 9%, respectively. For the other stations (1, 4, 5, 6, and 7), aromatics exhibit an increase in the round 2 values; station 4 shows the highest increase, about 21%. Conversely, sulfur content values exhibit a general decrease for all the stations except 4 and 6. Sulfur values range from a decrease of about 13% to an increase of about 9%. Station 2 indicates the largest decrease (13%), and station 6 indicates the largest increase (9%).

All the gasoline and diesel analysis data from round 1 and round 2 for the Houston district are provided in Attachment 5a. Attachment 5a includes the round 1 and round 2 raw sampling results received from SwRI. It also contains the data presented in Tables 5 and 6, as well as Houston district-level averages for selected fuel parameters for round 1 and round 2 sampling of gasoline and diesel fuel.

## 5.2 Trends Analysis (2020 Data vs. Data from Previous Years)

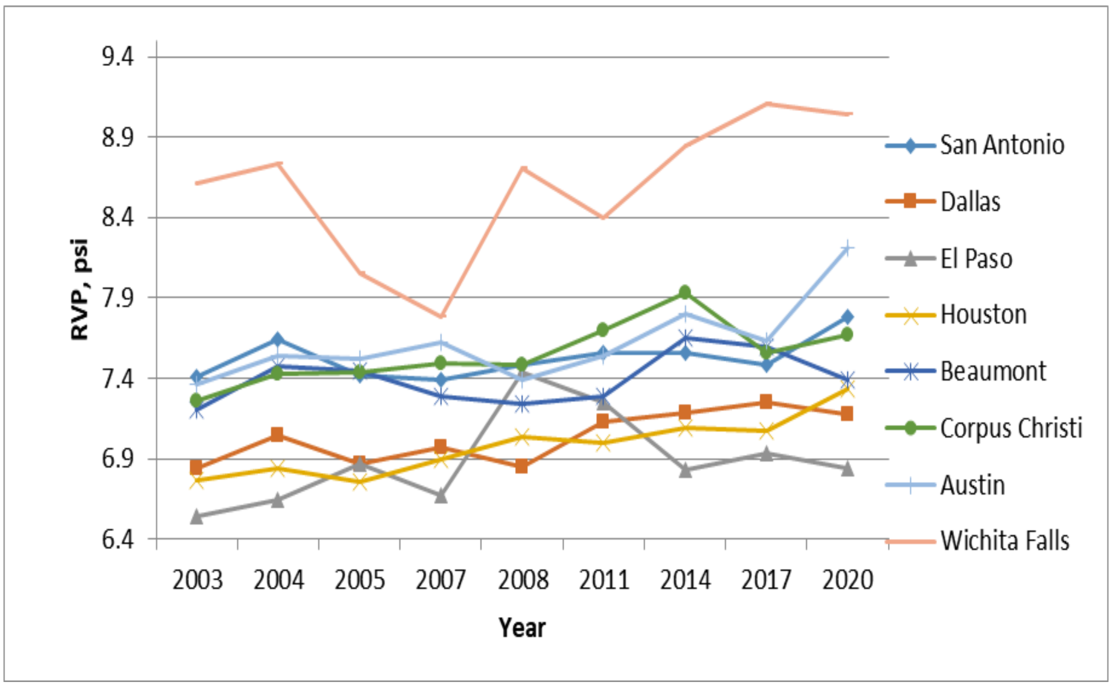
ERG compared the sampling results for gasoline and diesel fuel collected during the summer of 2020 with the results from the summers of 2003 through 2017. (Note that data from 2003–2017 are not available for all years: testing was not conducted in the summers of 2006, 2009, 2010, 2012, 2013, 2015, 2016, 2018, or 2019.)

For this trends analysis, ERG aggregated gasoline and diesel samples at the TxDOT District level and developed district-level averages.

Figures 2 through 13 illustrate the trends in selected gasoline fuel parameters for selected districts from 2003 through 2020. Figures 14 through 21 illustrate the diesel fuel composition trends from 2003 through 2020 for selected diesel fuel parameters and for selected districts. All the trends analysis data are provided in Attachment 5b.

Summer fuel studies performed in the past used results from ASTM D1319 testing for aromatics, olefins, and saturates for both diesel and gasoline fuel samples. ASTM D1319 testing was not performed during this project because the dye required for this testing does not meet current ASTM quality standards. Therefore, alternate tests were performed for aromatics (D5769) and olefins (D6550).

**Figure 2. Gasoline RVP Trends for Selected Districts[2]**




[2] Refer to page 28 for clarification on higher RVP values in Austin for 2020.

**Figure 3. Gasoline Sulfur Trends for Selected Districts**

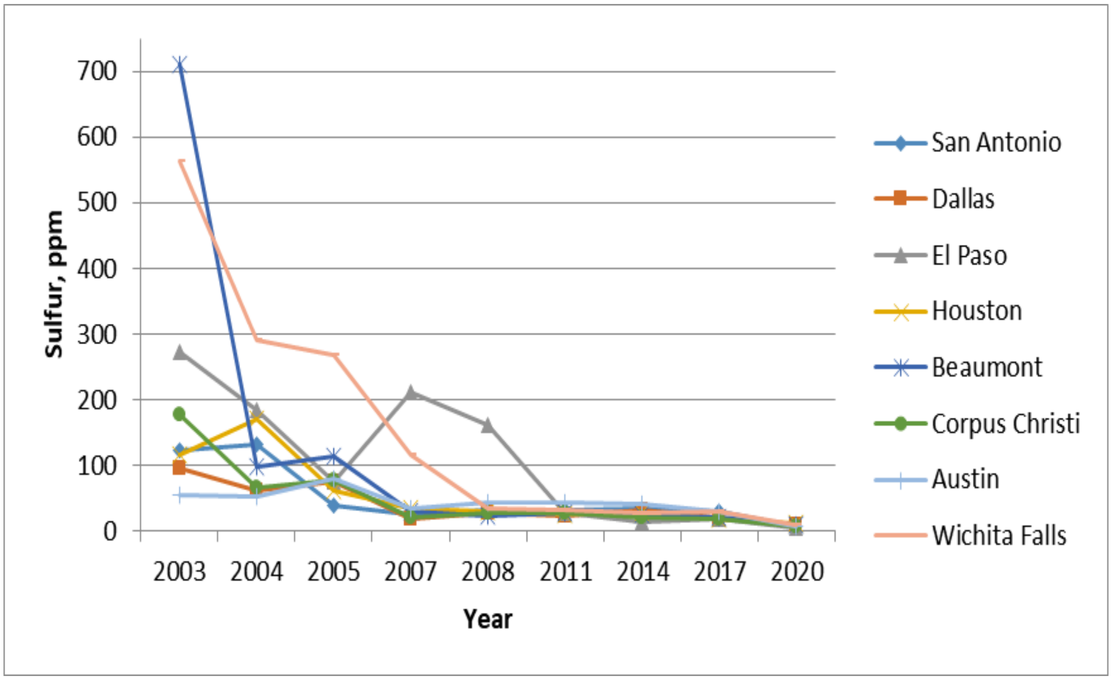



**Figure 4. Gasoline Sulfur Trends for Selected Districts (2011–2020)**

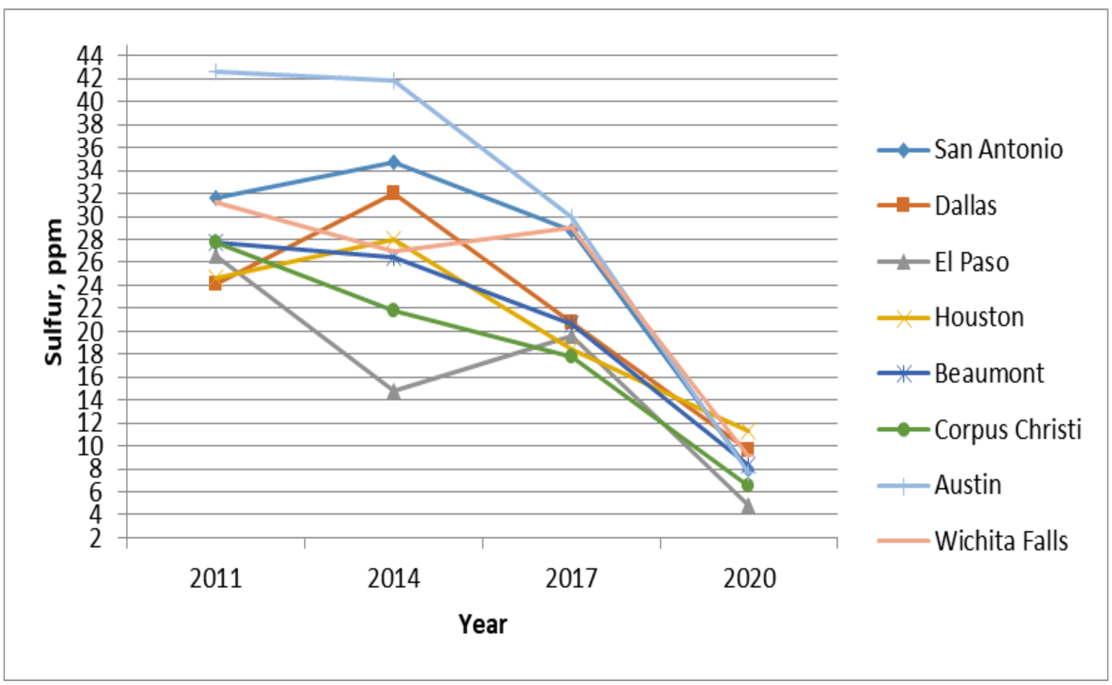


**Figure 5. Gasoline Olefins Trends for Selected Districts**

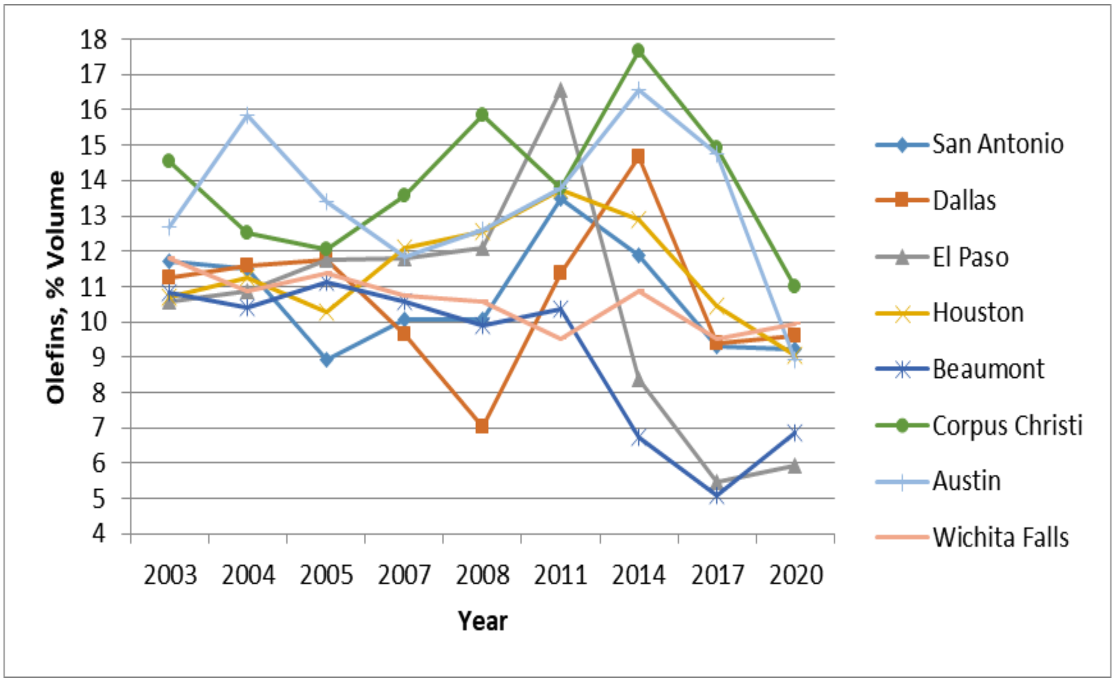



**Figure 6. Gasoline Aromatics Trends for Selected Districts**

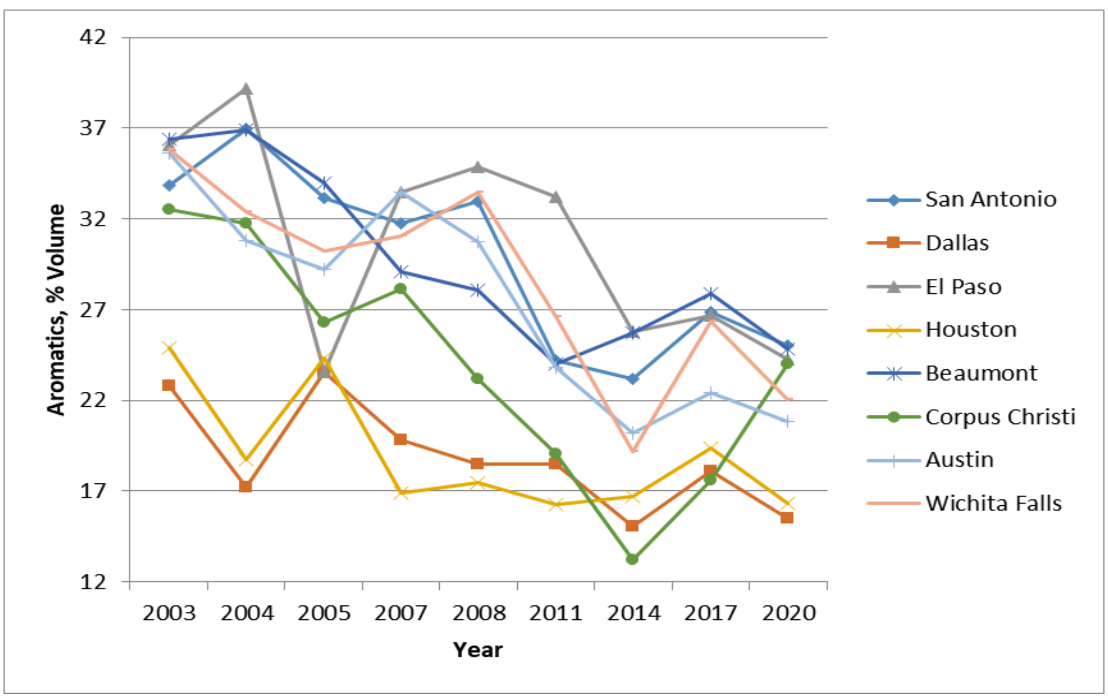


**Figure 7. Gasoline Benzene Trends for Selected Districts**

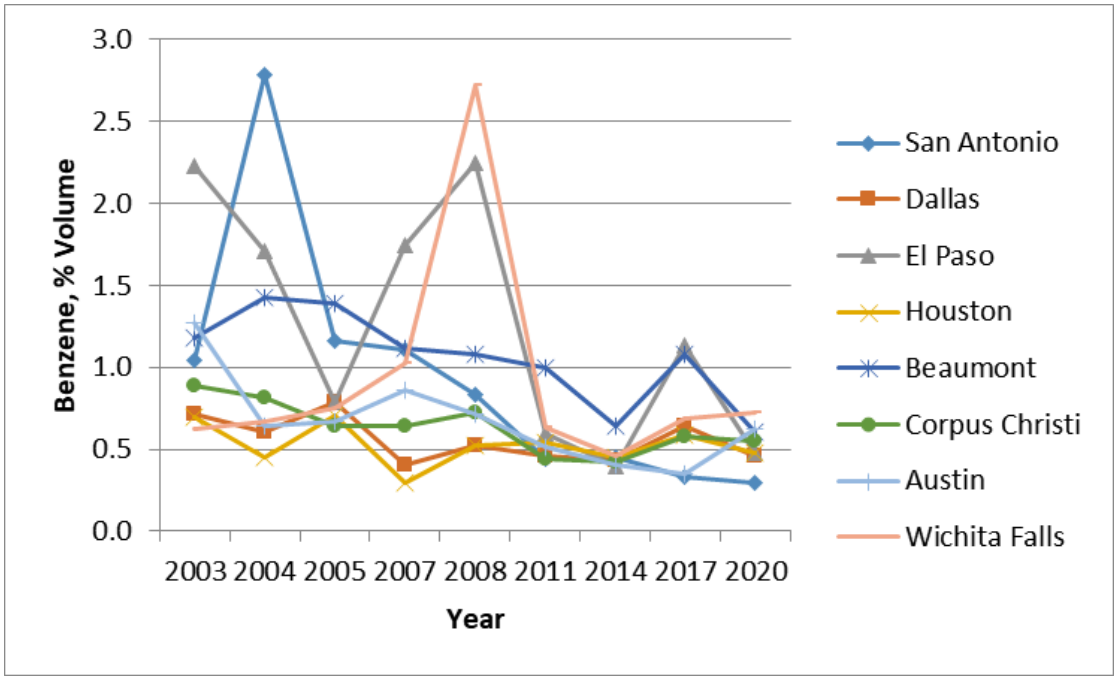



**Figure 8. Gasoline MTBE Trends for Selected Districts**

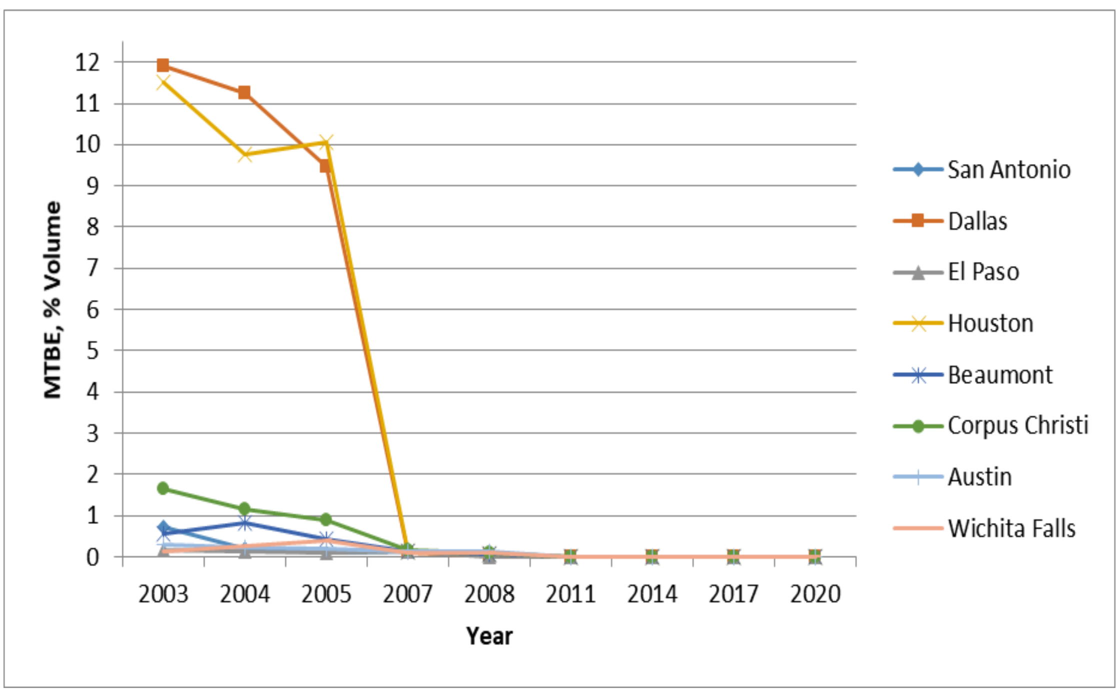


**Figure 9. Gasoline ETBE Trends for Selected Districts**

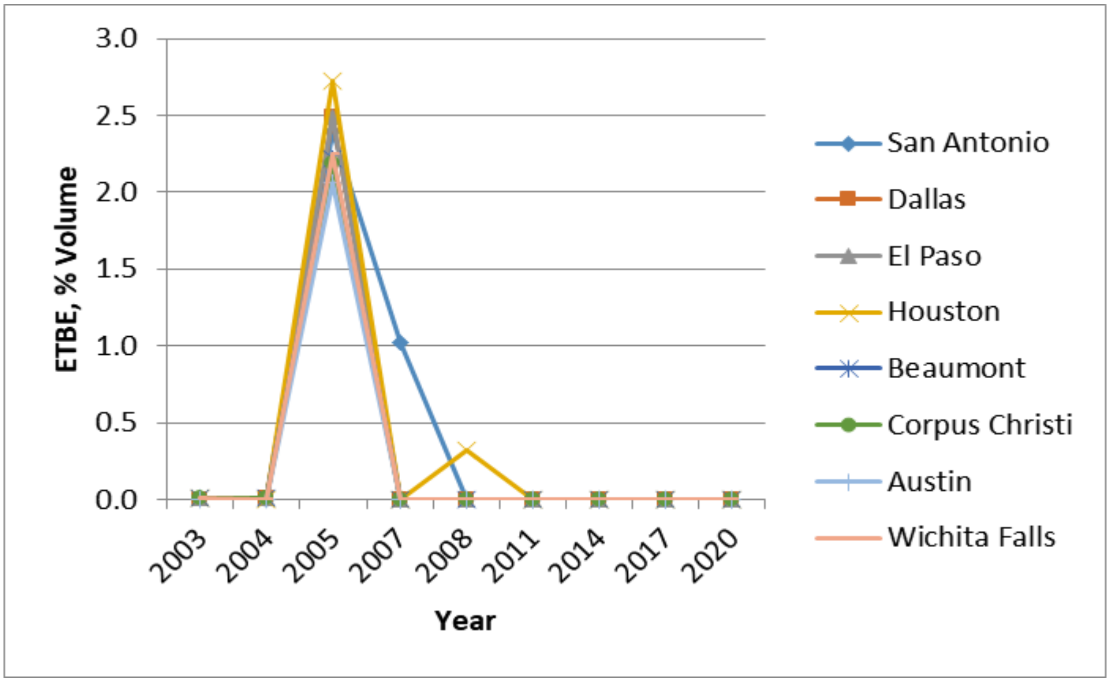



**Figure 10. Gasoline Ethanol Trends for Selected Districts**

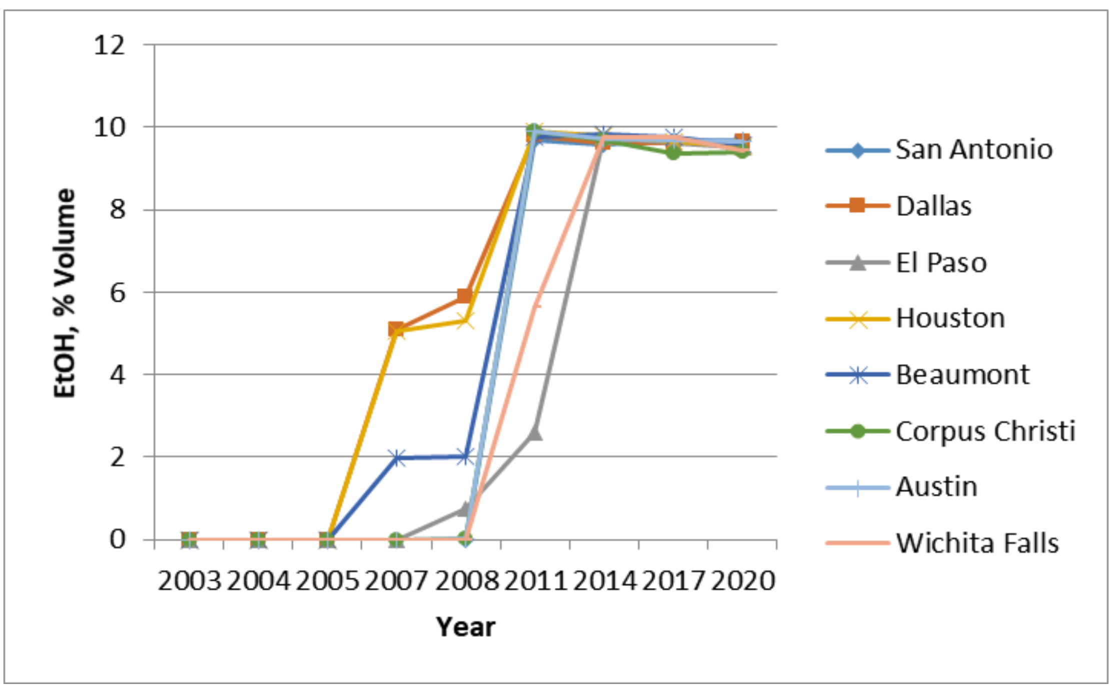


**Figure 11. Gasoline TAME Trends for Selected Districts**

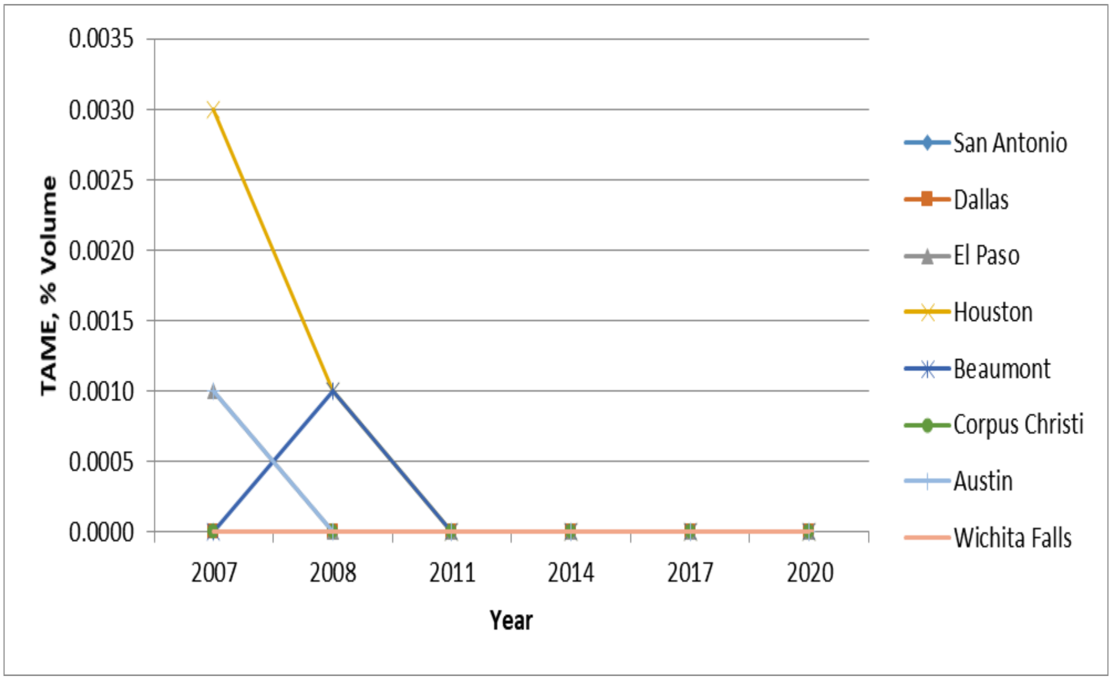



**Figure 12. Gasoline E200 Trends for Selected Districts**

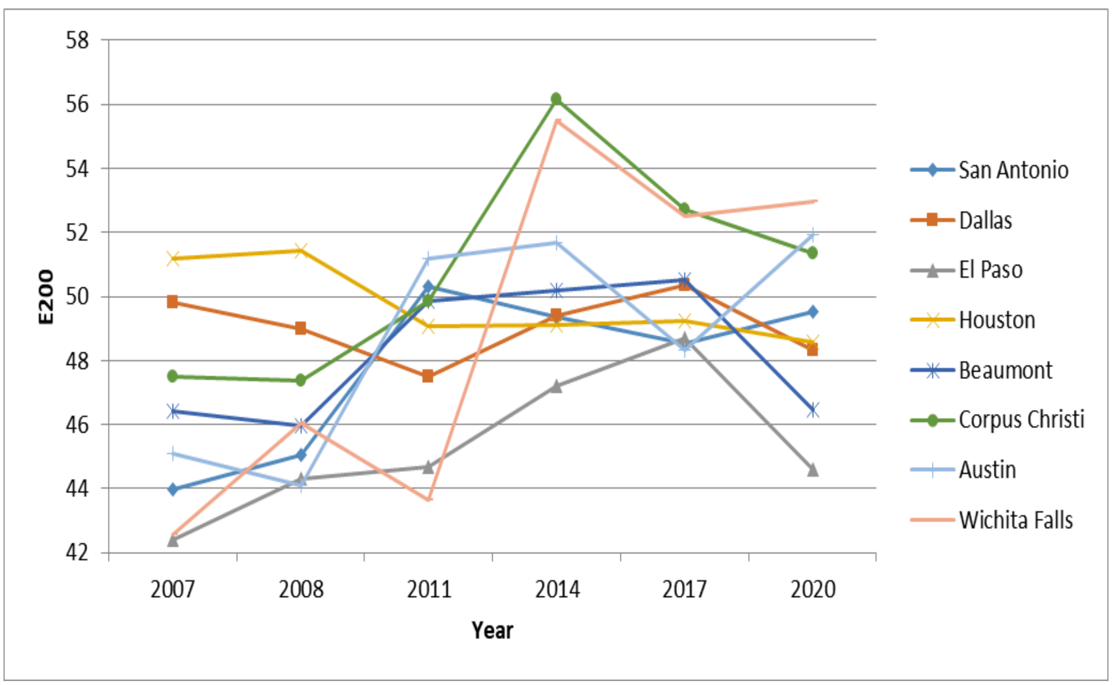
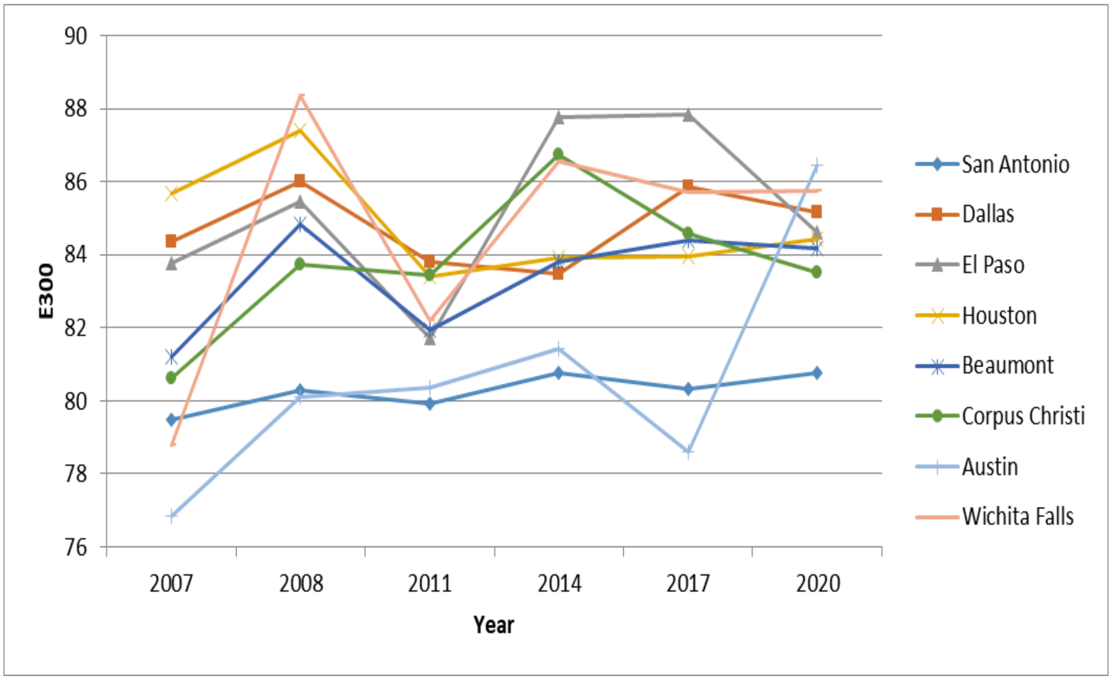


**Figure 13. Gasoline E300 Trends for Selected Districts**




ERG notes several general observations, described below, in the gasoline sampling data across the time-series.

- RVP in most districts appears to be relatively stable over time. Most values range from 6.5 to just under 8.0, except in Austin and Wichita Falls districts. For Wichita Falls, the RVP values range from 7.78 in 2007 to 9.11 in 2017. For Austin, the RVP values range from 7.36 in 2003 to 8.21 in 2020.

  Some of the gasoline samples had higher RVP than allowable under TCEQ's Regional Low Reid Vapor Pressure Gasoline Program (7.8 psi). Due to the COVID-19 pandemic, the U.S. EPA issued a federal waiver for summer gasoline fuel, effective from May 1 through May 20, 2020. The waiver was applicable to federal RVP standards and to federally-enforceable SIP covered areas in Texas. Any gasoline stocks on May 20 were allowed to be sold and distributed until the supply was depleted. Additionally, there was a decline in vehicle miles travelled and corresponding gasoline demand because of travel restrictions and local and state shelter in place orders due to the COVID-19 pandemic. For these reasons, it is assumed that some of the gasoline retail stations in Texas still had winter gasoline fuel in stock in June during round 1 sampling, especially for premium grade gasoline.

- Sulfur levels have been below 50 ppm since 2011, as expected with the current federal sulfur fuel standards. The lowest sulfur levels for all the districts were recorded in 2020, with values ranging from 4.9 ppm in El Paso to 11.3 ppm in Houston.
- There does not appear to be any obvious trend for olefins in most districts over time. Aromatics display a general downward trend since 2008. Benzene values also represent a downward trend since 2008 for all districts, except Dallas, El Paso, and Houston.
- Non-ethanol oxygenates (i.e., ETBE, TAME, and MTBE) were only observed in trace amounts, if at all. Ethanol values have been relatively stable for all the districts since 2014.
- E200 and E300 values have been relatively stable for all the districts since 2007.

**Figure 14. Diesel Sulfur Trends for Selected Districts**

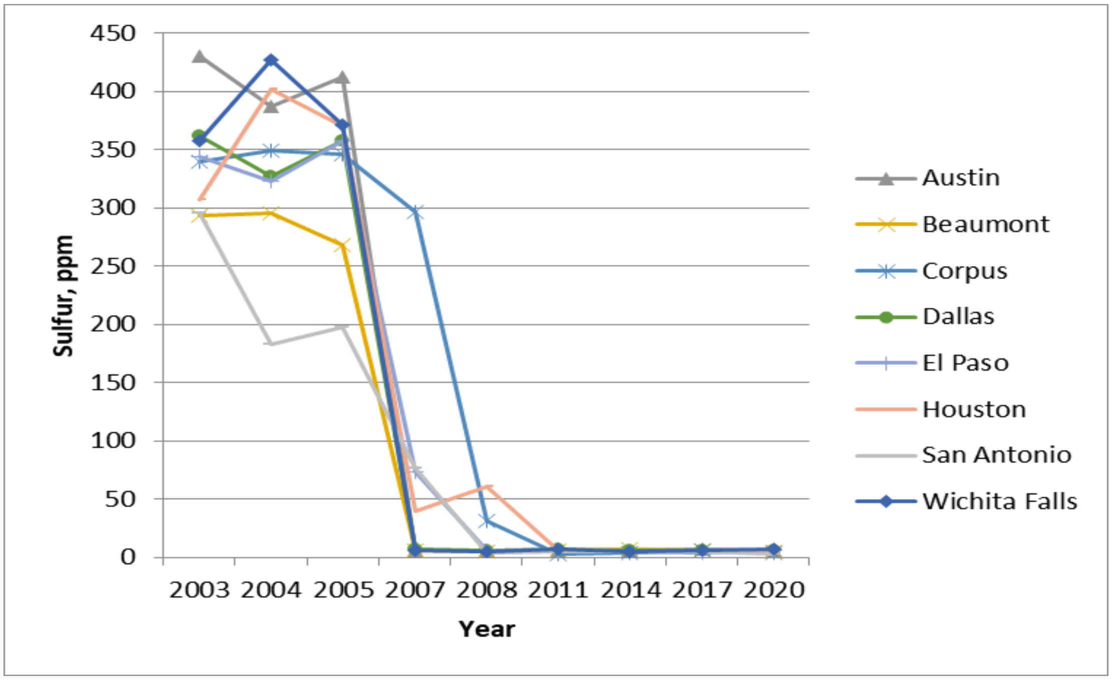



**Figure 15. Diesel Sulfur Trends for Selected Districts (2011–2020)**

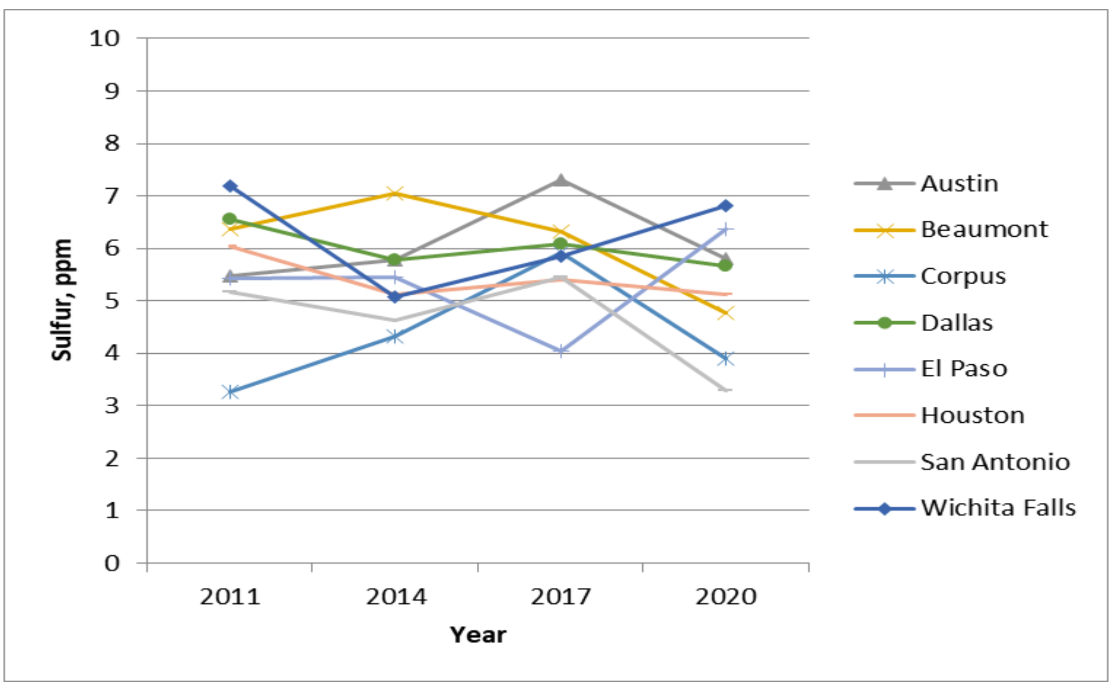


**Figure 16. Diesel Cetane Trends for Selected Districts**

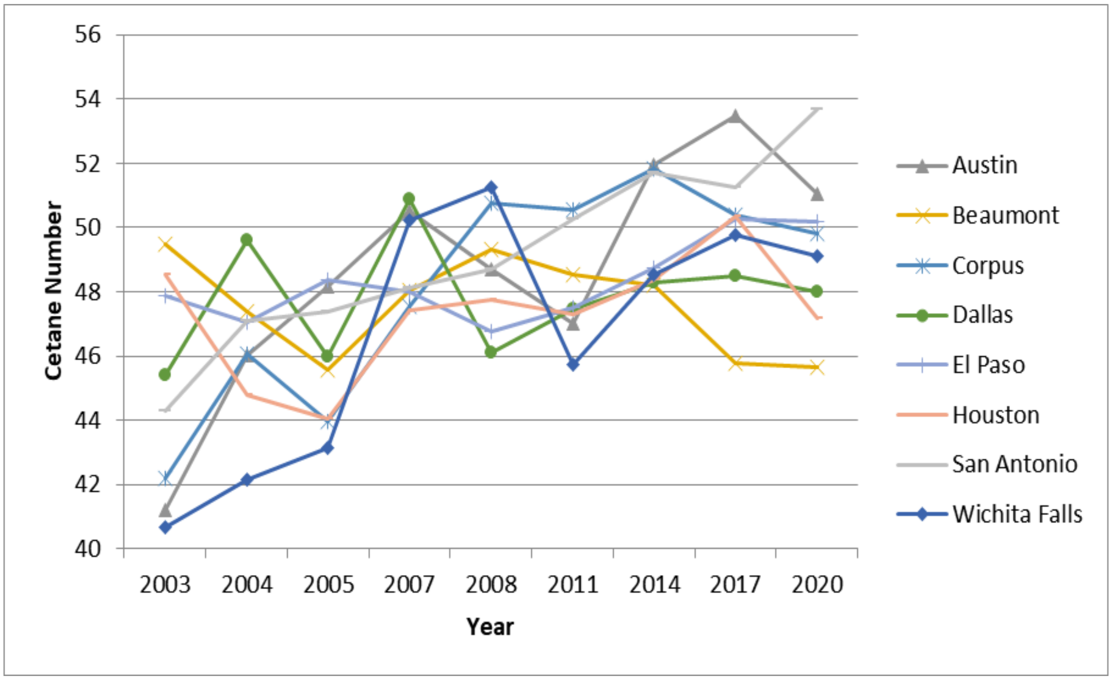



**Figure 17. Diesel Specific Gravity Trends for Selected Districts**

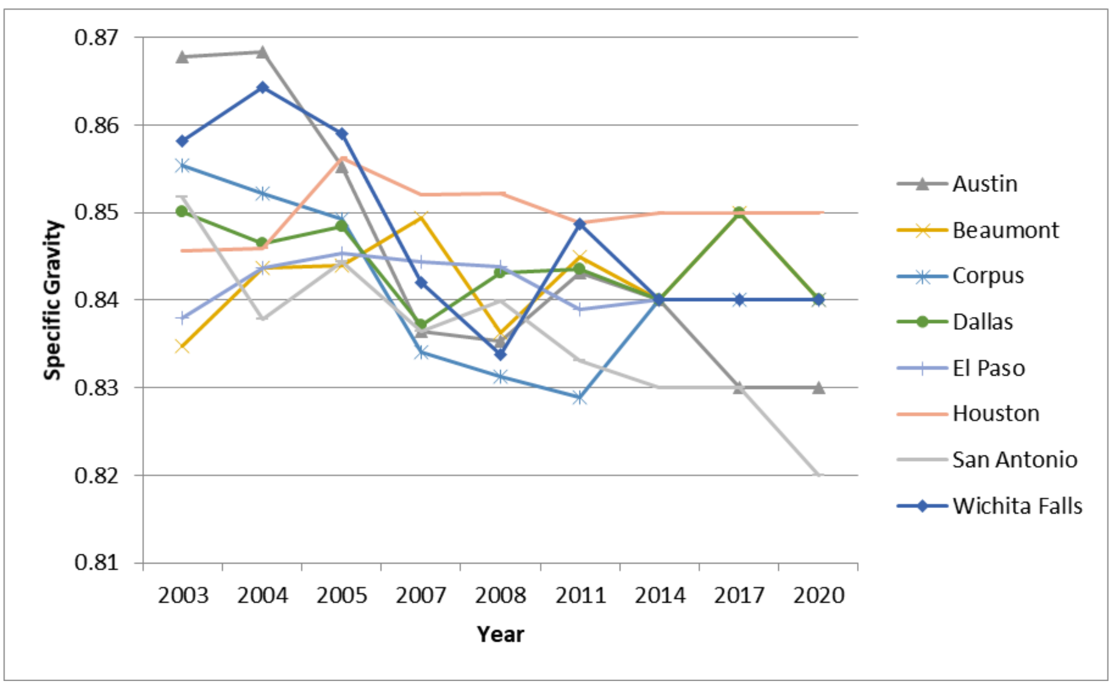
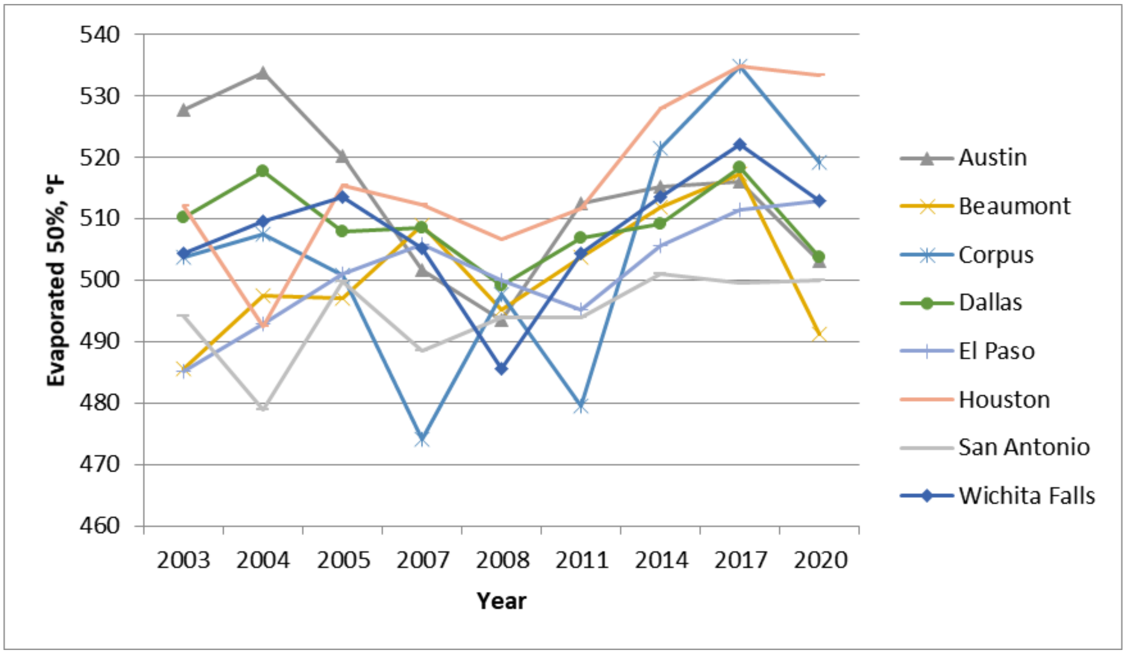


**Figure 18. Diesel T50 Trends for Selected Districts**




ERG notes the following general observations about the diesel fuel parameter trends.

- Sulfur content values exhibit a general downward trend from 2003 to 2020. There is a sharp decline from 2005 to 2007, with lower values trending through 2020. All districts had their peak average sulfur values during the 2003–2005 period. Since 2011, all districts had an average sulfur content value below 8 ppm.This trend is consistent with the federal ultra-low-sulfur fuel requirements. Sulfur content values in 2020 are below 7 ppm for all districts. Sulfur content in 2020 decreased from the 2017 levels for all districts except El Paso and Wichita Falls.
- Most districts exhibit a general upward trend for the average cetane number values, with the exception of Houston. For the Houston district, the cetane number values have been fairly stable, with the 2020 value being lower than the 2017 value.
- For specific gravity values, most districts display a general downward trend from 2003 through 2007. District-level specific gravity values have been stable since 2008, and there has not been much change from 2008 to 2020. The biggest change in specific gravity values for 2003–2020 is for the Austin district (-4.4% change from the 2003 value).
- The T50 values for the selected districts are tightly grouped between 474 and 535 degrees, with a slight upward trend starting in 2008. The largest change from 2017 levels to 2020 is for the Beaumont district (-5%).

# 6.0 QUALITY ASSURANCE

ERG reviewed the lab analysis results for all gasoline and diesel samples, looking for possible outliers or unusual data distributions. ERG evaluated the minimum, maximum, average, and standard deviation for lab testing results by TxDOT district in the 2003–2020 trends analyses. The values were then plotted against previous years and other districts to highlight possible outliers. Trend lines created during post-processing the lab results also aided in identifying outliers. No issues were identified with the 2020 sampling results.

Before ERG received the lab test results, SwRI performed rigorous QA/QC checks of the samples received and the equipment used during testing. These QA/QC procedures are described in detail below.

## 6.1 Calibrations and Quality Control Checks

### 6.1.1 Instrument/Equipment Calibration and Frequency

#### 6.1.1.1 Detailed Hydrocarbon Analysis, ASTM 6729-14

The instrument is calibrated by running the calibration standard containing the 400 plus components and verifying their identification using the provided chromatogram.

#### 6.1.1.2 Reid Vapor Pressure, ASTM D 5191-19

All instruments for this test are calibrated by an ISO 17025 accredited service company every 6 months.

#### 6.1.1.3 Sulfur, ASTM D 2622-16

The x-ray instruments for this test are calibrated annually with drift correction and calibration verification performed daily.

#### 6.1.1.4 Distillation, ASTM D 86-18

An in-house maintenance group calibrates all distillation rigs every three months. Each temperature probe is calibrated every 6 months using 100% toluene and hexadecane.

#### 6.1.1.5 Cetane Number, ASTM D 613-18a

The rating units are calibrated daily to the range of each sample.

#### 6.1.1.6 Total Aromatics, ASTM D 5769-15

The instruments are calibrated as needed and immediately after any instrument maintenance. A calibration verification is performed prior to any sample analysis.

#### 6.1.1.7 Olefins, ASTM D 6550-15

The instruments are calibrated as needed and immediately after any instrument maintenance. A calibration verification is performed prior to any sample analysis.

#### 6.1.1.8 Sulfur, ASTM D 5453-19a

Samples are analyzed using ultraviolet fluorescence. The instrument is calibrated as needed. A calibration verification is performed prior to any sample analysis.

#### 6.1.1.9 Specific Gravity, ASTM D 1298-12b (2017)

New calibrated hydrometers are acquired every twelve months to cover the range of gasoline and diesel samples.

#### 6.1.1.10 Flash point, ASTM D 93-19

The in-house maintenance group calibrates the temperature probe and stirrer rotation every 6 months.

#### 6.1.1.11 Nitrogen, ASTM D 4629-17

The instruments are calibrated as needed. A calibration verification is performed prior to sample analysis.

#### 6.1.1.12 Polycyclic and Total Aromatic, ASTM D 5186-19

The systems performance is set to meet ASTM D5186-19.

#### 6.1.1.13 Benzene, ASTM D 3606-19

Each instrument is calibrated as needed. A calibration verification is performed prior to any sample analysis. Every tenth sample and at the end of the tray, a QA sample containing benzene and ethanol is run to ensure instrument stability and performance. Purchased standards are also used for verification. Flow and valve timing is checked at a minimum of once a month and at any other time that non-routine maintenance is performed. Control charts are maintained and monitored daily for process stability for each instrument.

#### 6.1.1.14 Oxygenates, ASTM D 5599-18

Each chromatograph is calibrated with a standard set at regular intervals, and the calibration is verified daily before any sample run. The verification includes measurement of a set of QA/QC standards with internal standards. Several external standards are used that include varied concentrations of TAME, ethanol, and MTBE. A blank and one of the instrument calibration standards containing approximately 0.5% of each component are also included at the beginning of each tray to determine if proper resolution is being achieved on each column. Each sample contains an internal standard to correct for any variation in injection volume.

Two QA/QC samples are placed after every 10 samples and at the end of each tray. The QA/QC is run in duplicate to verify the instrument's precision. Regular instrument maintenance, multiple daily calibration checks, column performance checks and review of the gas chromatograph traces for excessive noise, drift, or other operational problems provide assurance that a system is in place that will generate quality data. Control charts are maintained and monitored daily for process stability for major oxygenate components for each instrument.

### 6.1.2 Quality Control

#### 6.1.2.1 Detailed Hydrocarbon Analysis, ASTM D 6729-14

The laboratory routinely monitors the repeatability and reproducibility of its analysis. The repeatability is monitored through the use of laboratory replicates at the rate of one per batch or at least one per 10 samples, whichever is more frequent. Reproducibility will be monitored through the use of a QC sample analyzed at the rate of one per batch or at least one per 15 samples, whichever is more frequent.

The range (R) for the duplicate samples should be less than the following limits.

| | |
|---|---|
| Benzene | 0.047*C |
| MTBE | 0.032*C |
| 2,2,4 Trimethyl pentane | 0.034*C |

Where:
$C = (C_o+C_d)/2$
$C_o$ = Concentration of the original sample
$C_d$ = Concentration of the duplicate sample
R = Range, $| C_o - C_d |$

The QC sample is plotted on an individual control chart and the upper and lower control limits are determined in accordance with OAE Standard Operating Procedure 4.20—Revision 5 *Statistical Methods*.

#### 6.1.2.2 Reid Vapor Pressure, ASTM D 5191-19

RVP systems are verified every 20 samples with a QC gasoline sample. The systems are verified with a 44.0:56.0 Pentane/Toluene blend every 6 months.

#### 6.1.2.3 Sulfur, ASTM D 2622-16

Sulfur is analyzed using the multi-point calibration curves specified in Method D 2622, which are stored in the system computer. At the beginning of each shift, the instrument is verified using a purchased QA standard. Drift corrections are applied as needed. Control charts are maintained on the sulfur procedure. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

#### 6.1.2.4 Distillation, ASTM D 86-18

Full instrument verification is conducted on each unit on an annual basis, and daily system verification is completed prior to running any sample at the start of each day. Control charts are maintained on each instrument, and a verified barometer is used for barometric correction of the data. Electronic parts are checked as specified in the lab calibration and recall schedule and at any time that non-routine maintenance is performed. This test is included in many of the regional and ASTM crosscheck programs in which SwRI participates.

#### 6.1.2.5 Cetane Number, ASTM D 613-18a

The rating units are calibrated daily to the range of each sample.

#### 6.1.2.6 Total Aromatics, ASTM D 5769-15

The results are monitored with three different QA samples. These samples are run in the same manner as the sample testing is performed. For every tenth sample, the three QA samples are run to ensure instrument stability and performance. Control charts are maintained on each instrument.

#### 6.1.2.7 Olefins, ASTM D 6550-15

The results are monitored with a QA sample. This sample is run in the same manner as the sample testing is performed. For every tenth sample, the QA sample is run to ensure instrument stability and performance. Control charts are maintained on each instrument.

#### 6.1.2.8 Sulfur, ASTM D 5453-19a

The instrument is monitored daily by running a quality control sample with known sulfur content. Control charts are maintained on each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

#### 6.1.2.9 Flash Point, ASTM D 93-19

The flash point results are monitored through daily verification with an anisole reference material and an annual verification using an Accu Standard ASTM-P-133-01 certified reference material. The instrument undergoes internal calibration every 6 months by internal calibration.

#### 6.1.2.10 Nitrogen, ASTM D 4629-17

The Antek instruments are monitored daily by running a quality control sample with known nitrogen content. Control charts are maintained on each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

#### 6.1.2.11 Polycyclic and Total Aromatics, ASTM D 5186-19

The Selerity Technology instrument is monitored daily by running a quality control sample with known aromatic content. Control charts are maintained for the instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

### 6.1.2.12 Benzene, ASTM D 3606-19

Each instrument is calibrated as needed using a curve with a series of calibration standards containing benzene from 0% to 5% and toluene from 0.5% to 20%. Every tenth sample and at the end of the tray, a QA sample containing benzene and ethanol is run to ensure instrument stability and performance. Control charts are maintained for each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

### 6.1.2.13 Oxygenate, ASTM D 5599-18

Each chromatograph is calibrated with a standard set at regular intervals, and the calibration is verified daily before any sample run. The verification includes measurement of a set of QA/QC standards with internal standards. Several external standards are used which include varied concentrations of TAME, ethanol, and MTBE. A blank and one of the instrument calibration standards containing approximately 0.5% of each component are also included at the beginning of each tray to determine if proper resolution is being achieved on each column. Each sample contains an internal standard to correct for any variation in injection volume. Control charts are maintained for each instrument. This test is included in many regional and ASTM crosscheck programs in which SwRI participates.

A QA/QC sample is placed every 10 samples and at the end of each tray. A QA sample is run in duplicate every 10 samples. Regular instrument maintenance, multiple daily calibration checks, column performance checks and review of the gas chromatograph traces for excessive noise, drift, or other operational problems provide assurance that a system is in place that will generate quality data. Control charts are maintained and monitored daily for process stability for major oxygenate components for each instrument.

## 6.2 Calibrations and Quality Control Acceptance Criteria

The SwRI laboratory staff conducted the initial data verification. They accepted or rejected the data based upon the QC samples and, if applicable, chromatography and laboratory replicates.

The SwRI Program Manager reviewed the data. The data were reviewed for apparent accuracy, completeness, and reasonableness. The SwRI Program Manager decided whether to validate, rerun, or invalidate the data based on their review.

### 6.2.1 Detailed Hydrocarbon Analysis, ASTM D 6729-14

Since typical gasoline is a mixture of over 400 components, it would be impractical if not impossible to impose data quality indicators on each analyte of interest. Therefore, one component from each of the functional groups was tracked to assess the overall quality of the analytical performance.

**Table 7. Data Quality Indicators—Detailed Hydrocarbon Analysis (ASTM D 6729-14)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | The difference between replicate results, in the normal and correct operation of the method, should not exceed the following values expressed as percentages of the average of the two values:<br>4.7 % Benzene<br>3.2 % MTBE<br>3.4 % 2,2,4 Trimethyl pentane |
| Bias | The bias of this test method cannot be determined since an appropriate standard reference material is not available. It is impossible to account for every potential co-elution and quantify the magnitude of the interference. | N/A |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Since a suitable reference material is not available, Accuracy will be maintained by a QC sample. | The 95% confident interval limits for the QC sample should be as follows expressed as percentages of the average of the two values:<br>9.9 % Benzene<br>8.9 % MTBE<br>9.5 % 2,2,4 Trimethyl pentane |
| Representative | Fuel samples will be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data set is defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions if the measurement technique. And in the case of petroleum chemistry are generally not quantifiable. The data set should give a reasonable estimate of the component distribution in the fuel supply but it may not be directly comparable to other methods. | N/A |

**Table 7. Data Quality Indicators—Detailed Hydrocarbon Analysis (ASTM D 6729-14)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | Based on the cooperative study results, individual component concentrations and precision are determined in the range of 0.01% mass to approximately 30% mass. | See ASTM D 6729-14 |

### 6.2.2 Reid Vapor Pressure, D 5191-19

**Table 8. Data Quality Indicators—RVP (ASTM D 5191-19)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D 5191-19 |
| Bias | There is no accepted reference material suitable for determining the bias for the procedures in this test method. Bias cannot be determined. | N/A |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D 5191-19 |
| Representative | Fuel samples will be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | Upper and lower vapor pressure limits are defined in Table 1 of ASTM D 5191-19. | See ASTM D 5191-19 |

### 6.2.3 Sulfur, ASTM D2622-16

**Table 9. Data Quality Indicators—Sulfur (ASTM D 2622-16)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D 2622-16. |
| Bias | Sulfur bias is detailed in D 2622-16. | See ASTM D 2622-16 |

**Table 9. Data Quality Indicators—Sulfur (ASTM D 2622-16)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D 2622-16. |
| Representative | Fuel samples will be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | N/A | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | Test method covers the determination of total sulfur in gasoline and diesel fuel. | See ASTM D 2622-16. |

### 6.2.4 Distillation, ASTM D 86-18

**Table 10. Data Quality Indicators—Distillation (ASTM D 86-18)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D 86-18. |
| Bias | Due to the use of total temperature probes, the distillation temperatures in this test method are somewhat lower than the true temperatures. The amount of bias depends on the product being distilled and the thermometer used. The bias due to the emergent stem has been determined for toluene and is shown in ASTM D 86-18. | N/A |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D 86-18 |
| Representative | Fuel samples will be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | The method is designed for the analysis of distillate fuels; it is not applicable to products containing appreciable quantities of residual material. | See ASTM D 86-18 |

### 6.2.5 Cetane Number, ASTM D 613-18a

**Table 11. Data Quality Indicators—Cetane Number (ASTM D 613-18a)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D 613-18a. |
| Bias | The procedure in this test method for cetane number of diesel fuel oil has no bias because the value of cetane number can be defined only in terms of the test method. | N/A |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D 613-18a. |
| Representative | Fuel samples will be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | The cetane number scale range from zero to 100 but typical testing is in the range of 30 to 65 cetane number. | See ASTM D 613-18a. |

### 6.2.6 Total Aromatics, ASTM D 5769-15

**Table 12. Data Quality Indicators—Total Aromatics (ASTM D 5769-15)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D5769-15. |
| Bias | Bias cannot be determined because there are no acceptable reference materials suitable for determining the bias for the procedure in this test method. | See ASTM D5769-15. |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D5769-15. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the test method. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |

**Table 12. Data Quality Indicators—Total Aromatics (ASTM D 5769-15)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
| --- | --- | --- |
| Sensitivity | This test method covers the determination of total aromatics in gasolines. This test method has been tested for the following concentration ranges, in liquid volume percent, for the following aromatics: benzene, 0.1% to 4%; toluene, 1% to 13%; and total (C6 to C12) aromatics, 10% to 42%. | See ASTM D5769-15. |

### 6.2.7 Olefins, ASTM D 6550-15

**Table 13. Data Quality Indicators—Olefins (ASTM D 6550-15)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
| --- | --- | --- |
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D6550-15. |
| Bias | Bias cannot be determined because there are no acceptable reference materials suitable for determining the bias for the procedure in this test method. | See ASTM D6550-15. |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D6550-15. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the test method. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | This test method covers the determination of total amount of olefins in gasolines. The application range is from 1 mass % to 25 mass % total olefins. | See ASTM D6550-15. |

### 6.2.8 Sulfur, ASTM D 5453-19a

**Table 14. Data Quality Indicators—Sulfur (ASTM D 5453-19a)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
| --- | --- | --- |
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. | See ASTM D 5453-19a. |

**Table 14. Data Quality Indicators—Sulfur (ASTM D 5453-19a)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Bias | Bias study is documented in ASTM Research Report RR-D02-1307 (1992). The report indicated that the bias is within repeatability of the test method. | See ASTM D 5453-19a. |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D 5453-19a. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | This method covers the determination of total sulfur in liquid hydrocarbons, boiling in the range of 25 to 400 °C with viscosities of 0.2 and 20 cSt at room temperature. | See ASTM D 5453-19a. |

### 6.2.9 Flash Point, ASTM D 93-19

**Table 15. Data Quality Indicators—Flash point (ASTM D 93-19)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. | See ASTM D 93-19. |
| Bias | There is no accepted reference material suitable for determining the bias for the procedure in these test methods, bias has not been determined. | N/A |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). | See ASTM D 93-19. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |

**Table 15. Data Quality Indicators—Flash point (ASTM D 93-19)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Sensitivity | This test method covers the determination of flash point of petroleum products in the temperature range 40 to 360 °C by manual Pensky-Martens closed cup apparatus or an automated Pensky-Marten closed cup apparatus. | See ASTM D 93-19. |

### 6.2.10 Nitrogen, ASTM D 4629-17

**Table 16. Data Quality Indicators—Nitrogen (ASTM D 4629-17)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. | See ASTM D 4629-17. |
| Bias | The bias cannot be determined since an appropriate standard reference material containing a known trace level of nitrogen in a liquid petroleum hydrocarbon is not available to form the basis of a bias study. | N/A |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). | See ASTM D 4629-17. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | This test method covers the determination of the trace total nitrogen naturally found in liquid hydrocarbons boiling in the range of 50 to 400 °C with viscosities between 0.2 and 10 cSt at room temperature. | See ASTM D 4629-17. |

### 6.2.11 Polycyclic and Total Aromatics, ASTM D 5186-19

**Table 17. Data Quality Indicators—Polycyclic and Total Aromatics (ASTM D 5186-19)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. | See ASTM D 5186-0319. |

### Table 17. Data Quality Indicators—Polycyclic and Total Aromatics (ASTM D 5186-19)

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Bias | Reference materials for this test method are in development through ASTM. The bias cannot be determined at this time. | N/A |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). | See ASTM 5186-19. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | The resulting data are defined only in terms of the method. Various analytical techniques that purport to report the same property have systematic biases that are functions of the measurement technique. | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | This test method covers the determination of the total amounts of monoaromatic and polynuclear aromatic hydrocarbon compounds in motor diesel fuel by SFC. The range of aromatics concentration to which this test method is applicable is from 1 to 75 mass %. The range of polynuclear aromatic hydrocarbon concentrations to which this test method is applicable is from 0.5 to 50 mass %. | See ASTM 5186-19. |

## 6.2.12 Benzene, ASTM D 3606-19

### Table 18. Data Quality Indicators—Benzene (ASTM D 3606-19)

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D 3606-19. |
| Bias | Benzene bias is detailed in D 3606-17. | See ASTM D 3606-19. |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D 3606-19. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | N/A | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | Benzene can be determined between the levels of 0.1 and 5 volume %. | See ASTM D 3606-19. |

### 6.2.13 Oxygenates, ASTM D 5599-18

**Table 19. Data Quality Indicators—Oxygenates (ASTM D 5599-18)**

| DQI | Definition/Discussion | Measurement Performance Criteria |
|---|---|---|
| Precision | Precision in analytical petroleum chemistry is generally given in terms of repeatability. (Short term) | See ASTM D 5599-18. |
| Bias | Oxygenate bias is detailed in D 5599-18. | See ASTM D 5599-18. |
| Accuracy | Accuracy in analytical petroleum chemistry is generally defined in terms of reproducibility (long term). Accuracy will be maintained by a QC sample. | See ASTM D 5599-18. |
| Representative | Fuel samples are to be collected by field contractors at locations defined by ERG. | N/A |
| Comparability | N/A | N/A |
| Completeness | All samples received by SwRI will be analyzed according to the protocol. Should any sample be compromised, SwRI will supply a replacement sample. | 100% |
| Sensitivity | Test method covers a gas chromatographic procedure for the quantitative determination of organic oxygenated compounds in gasoline having a boiling point limit of 220°C and oxygenates having a boiling point limit of 130°C. It is applicable when oxygenates are present in the 0.1 to 20% by mass range. | See ASTM D 5599-18. |

## 6.3 Data Auditing

SwRI reviewed the sample collection receipts for all samples collected to ensure the proper grade was acquired and samples were obtained from designated retail outlets. SwRI also audited the steps of analysis for 30 of the samples taken (> 10%), as required by Category III projects. No data outliers/errors were identified during the audit.

## 7.0 REFERENCES

ERG, 2017. "2017 Summer Fuel Field Study." Final report prepared for Texas Commission on Environmental Quality (TCEQ) by Eastern Research Group, Inc. (ERG). August 31, 2017.

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Regan, 2020. TCEQ petroleum storage tank (PST) data provided via email by Michael Regan (TCEQ), February 2020.

# ATTACHMENT 1:

**Final Sampling Station List**
***(provided electronically)***

# ATTACHMENT 2:

## SwRI Testing Results for Gasoline
*(provided electronically)*

# ATTACHMENT 3:

## SwRI Testing Results for Diesel
*(provided electronically)*

# ATTACHMENT 4a:

**Updated Fuel Parameter Files for MOVES2014b and TexN2**
***(provided electronically)***

## ATTACHMENT 4b:

**Gasoline and Diesel Analysis Data and Results**
***(provided electronically)***

# ATTACHMENT 5a:

**Round 2 Sampling Test Results,**
**Round 1 vs. Round 2 Analysis Data and Results**
***(provided electronically)***

## ATTACHMENT 5b:

**Trends Analysis Data and Results**
***(provided electronically)***